ENGINEERING-TEST REPORT ON

SHORT-RANGE MISSILE LAUNCH LOCATOR AN/TNS-5

Murray Goldstein

August 1962

UNITED STATES ARMY
ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY

FORT MONMOUTH, N.J.

U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

USAERADL Test Report 1505 has been prepared under the supervision of
the Director, Surveillance Department, and is published for the information
and guidance of all concerned. Suggestions or criticisms relative to the
form, contents, purpose, or use of this publication should be referred to
the Commanding Officer, U. S. Army Electronics Research and Development
Laboratory, Fort Monmouth, New Jersey, Attn: Chief, Reconnaissance Branch,
Applied Physics Division.

                                    J. M. KIMBROUGH, JR.
                                    Colonel, Signal Corps
                                    Commanding

OFFICIAL:
  HOWARD W. KILLAM
  Major, Sig C
  Adjutant

DISTRIBUTION:
  Special

ENGINEERING-TEST REPORT ON SHORT-RANGE MISSILE LAUNCH LOCATOR AN/TNS-5

Murray Goldstein

DA TASK NR. 3D58-05-001-07-01

U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

CONTENTS

CONTENTS (Cont)

ENGINEERING-TEST REPORT ON SHORT-RANGE MISSILE LAUNCH LOCATOR AN/TNS-5

INTRODUCTION

is presented

This report provides technical data on the performance of Short-Range Missile Launch Locator AN/TNS-5 ~~during tests conducted at this Laboratory and at Fort Sill, Oklahoma.~~ The equipment ~~was developed under Signal Corps Contract DA36-039 SC-75034 by Radio Corporation of America~~. The report is divided into two sections--Laboratory Tests and Field Tests:

a. Laboratory tests, ~~conducted at USAERADI~~, were concerned primarily with the technical characteristics of the AN/TNS-5. This equipment was tested in a carefully controlled laboratory environment. The tests measured compliance with Signal Corps Technical Requirements SCL-1830, and furnished quantitative data which appear under the individual test descriptions. ~~More specialized test procedures are described in the Appendix.~~

b. Field tests, conducted at Fort Sill, Oklahoma, were concerned with the performance of the AN/TNS-5 when operated under simulated combat conditions.

Numerous deficiencies found during the tests are summarized at the end of this report and corrective measures are recommended.

GENERAL DESCRIPTION

The Short-Range Missile Launch Locator AN/TNS-5 is the most recent in a series of equipment developments based upon the theory of the square microphone array. This arrangement permits the sound-ranging operator at any station to determine with considerable precision the direction of an enemy target with respect to his own position. Similar data is derived from other azimuth stations operating along a common baseline. This data is then transmitted to a common point where it is analyzed to yield a series of intersections which represents the source of the sound.

The present system consists of three engineering-test models, AN/TNS-5, which represent the minimum number of azimuth stations required for a complete sound ranging system. Each azimuth station includes the following major components:

a. <u>Tape transport</u> records incoming signals on a magnetic tape, which has four signal channels corresponding to a four-microphone array.

b. <u>Oscilloscope</u> permits the operator to view the previously recorded signals on the magnetic tape in the tape transport. The recorded data from

1

all four channels are seen simultaneously on the oscilloscope tubes; however, their relative positions may be shifted laterally in either direction by the operator or they may be overlaid to permit closer matching. The process of aligning signals coincidentally sets the positions of precision potentiometers mounted in the tape transport.

c. Computer (electromechanical analog) converts the output from the potentiometers into a direct reading of the target position with respect to grid north.

d. Capacitor microphones (four in use and two spares) act as transducers to convert the sounds of the artillery firings into equivalent electrical signals. When installed, the microphones are arranged in rectangular arrays, which may vary from 50 to 600 meters in size, measured diagonally.

e. Junction box provides a terminus for the microphones and a power input for the battery supply; it is also used as a shipping case for the microphones.

f. Battery BB-424/U, 24-volt, 24-ampere-hour, nickel-cadmium, provides power for 4 hours of continuous operation. One battery is supplied for each station; however, two batteries are provided so that one may be switched without interrupting operation.

The following auxiliary items, although not included with the present equipment, are essential for normal operation:

g. Radio or telephone to maintain communications between stations.

h. Battery charger.

i. Digital computer to correlate data received from the various stations.

In order to synchronize the timing mechanisms among the different stations, one station is designated as the "Master," and the other as "Slaves." The designation is arbitrary inasmuch as any station can perform either function.

PHYSICAL CHARACTERISTICS

The AN/TNS-5 is packaged in several shipping cases: Two large shipping cases contain the oscilloscope and the tape transport; two smaller cases contain the analog computer and the junction box; and another case contains one BB-424/U nickel-cadmium battery.

Weights of AN/TNS-5 Components

Junction Box	- 52 pounds	(without microphones - 43 pounds)
Oscilloscope	-143 pounds	(without case - 27½ pounds)
Battery	- 55 pounds	
Computer	- 30 pounds	
Tape Transport	-233 pounds	(without case - 81 pounds)

LABORATORY TESTS

General

The equipment is so designed that it is operable either in or out of the shipping cases. It is readily placed in operation by removing the covers from the shipping cases and screwing demountable legs into the bottom of the cases. The lengths of the legs are adjustable to allow for use on uneven ground. Detachable coupling cables join the major components.

An initial warmup period is necessary after the power is first applied. This allows the servo to settle down (about 2 minutes) and the ultrastable oscillator to stabilize (about 15 minutes). During this time the operator hooks up his microphones and telephone lines and performs other routine tasks.

Record Medium

Signals are recorded on a 5/8-inch-wide mylar magnetic tape which accommodates four signal channels and two skew-correction channels. The tape is supplied in the form of an endless loop 300-feet long and is imprinted with a numbering sequence of 0-14,400. The tape moves at a quarter of an inch per second permitting a storage capacity of 4 hours after which any previously stored information is automatically erased and a new timing cycle begins. The design of this tape presented many difficult problems, some of which are described below:

Tape Snarls

The tape frequently failed to follow the prescribed path and became badly snarled in the tape transport. The equipment then had to be shut down until the operator had relieved this condition. At worst this trouble occured several times a day. Aside from the annoyance, the many creases that were formed in the tape may eventually affect its life and performance.

Tape jams occur most frequently in hot and humid weather and in equipment that has been standing idle. Additional trouble occurs when a large loop is permitted to accumulate in the intermediate storage bin. The tape then often becomes snarled or the added weight prevents the playback capstan from lifting the tape from the bin. Two tapes split at Fort Sill after operators put excessive tension on them while attempting to clear tape snarls. Broken tapes must be discarded since they cannot be spliced without losing the timing sequence.

Tape Contrast

The photographic coating developed by an RCA subcontractor is translucent so that the dark magnetic oxide base shows through and degrades contrast. This not only reduces legibility but interferes with the performance of the photoelectric assembly, which stabilizes tape speed through a servo system. Much improvement is needed.

Tape Life

It is estimated on the basis of tests that the life expectancy of the magnetic tape in constant use would be about six months. After this time, breakage would occur, or surface scratches would reduce legibility to the point where the tape would no longer be usable.

Waiting Interval

At $\frac{1}{4}$-inch per second tape speed, and with no tape in storage, the tape requires almost a minute to traverse the path between the record and playback heads. This delay is undesirable.

Timing Error

The timing hairline for the record head is physically displaced from the recording gap by 10 seconds of tape time. To determine the time of an event, therefore, the operator reads the record time and subtracts ten. For example, a signal viewed on record at 1000 on the magnetic tape will appear on the scope screen when the tape passing over the playback head reads 990. This places an additional burden on the operator when it is necessary to observe the time over the record head.

Playback Head

Specification Requirement: paragraph 3.1.4.

A development of some interest for the AN/TNS-5 is a rotating playback head with built-in preamplifiers. During playback the magnetic tape is wrapped 180° around the cylindrical playback head and remains stationary while the head rotates at a rate of 20 revolutions per second beneath it. Despite mutual abrasion, both the head and tape stood up well. For example, after several hours of operation in a fixed position, the wear on the tape was confined to a slight burnishing of its magnetic surface. Conversely, the head withstood continuous rubbing from the tape for cumulative periods of several hundred hours without apparent degradation or wear. Based upon present experience, therefore, the life expectancy of the playback head is commensurate with other components in the equipment.

On the negative side, some additional stiffening in the head mounting is required to prevent a whipping motion which occasionally develops. A better brush assembly is also needed to control contact noise.

Field of View

Spec. Requirement - none.

A 5-point switch is provided for adjusting the operators field-of-view from 80 to 4000 milliseconds. When using the 4000-millisecond field, the veeder-root counters are out of the circuit and the times of arrivals of the signals appear in their true relationship. This feature permits the operator to recognize and reject unwanted signals such as those coming from the rear.
Switching the field-of-view causes a pronounced displacement of the signal on the oscilloscope screen so that the operator must find and re-center the signal each time the field width is varied. Since this action is accomplished by moving the tape back and forth in relation to the timing hairline, the apparent arrival time of the signal will vary appreciably with different fields of view. To meet this problem in the field, an operating procedure was established in which all stations made their time measurements on the 680-millisecond scale. Some signal displacement was also noted with respect to the selection of audio filter response, but this was not of sufficient magnitude to cause concern.

In addition to the timing errors described above, the shifting of the signal is troublesome in that it prevents the operator from "closing-in" on the signal by progressive reductions in the field-of-view. This defeats one of the principle objectives in providing a graduated system of sweep-times.

Ultrastable Oscillator

Spec. Requirement: paragraph 3.1.6.

The oscilloscope contains a transistorized, ultrastable oscillator in which a 1.310720 Mc crystal unit operates inside a proportionately controlled oven. Tests performed at USAERADL show a frequency stability of 1 part in 10^7 over a 24-hour period.

The signal from the oscillator is used to drive a series of binary frequency dividers which reduce its frequency by a factor of 2^{17} to give a final output of 10 cps. This signal serves as a time reference which controls the speed of the magnetic tape over the record head. The absolute frequency of the oscillator is not critical, although it is important that all stations operate at the same frequency so as to maintain tape synchronism.

To tune the oscillator, a slug adjustment was originally available from the front panel; however, this proved to be a weak point because of marginal design in the internal coupling. After repeated failures at this point, a modification was performed by the contractor wherein the oscillator frequency was adjusted through a combination of a voltage sensitive capacitor and a 10-turn potentiometer. This corrected the difficulty.

Oscillator Synchronization

Before transmitting the 1.3 Mc standard frequency signal from the master to the slave stations, it must first be divided by a factor of 512, through a series of flip-flops. This reduces the output frequency to 2560 cps which, being in the audio range, is readily transmitted over conventional radio or telephone lines. At the receiving end, the 2560-cycle reference signal is compared against a similar local signal by means of Lissajous patterns.

While this method appears relatively simple, it is poorly conceived from a systems standpoint. In dividing the crystal frequency by 512, the errors in the output frequencies are reduced by a similar factor. Since the maximum error likely to be experienced at the fundamental is only $\pm$ 2.5 cps, the Lissajous pattern formed at the subharmonic frequency will require at least 100 seconds to go through one revolution. At this rate of rotation, the circle appears practically stationary.

The procedure recommended by the contractor calls for stopping the Lissajous pattern on its edge. To do this the operator must adjust the tuning potentiometer very precisely, in order to halt its almost imperceptible motion. The difficulty is aggravated by 2nd harmonic distortion in the signal, which prevents reduction of the Lissajous pattern to line width. Student operators were unable to perform this operation, despite repeated efforts.

Remarks

The present method of synchronizing the ultrastable oscillators is considered impractical. The indicated correction is to multiply the subharmonic signal back to 1.3 Mc, and compare signals at the fundamental. This would reduce both the time and the level of skill required for this operation.

Tape Synchronization

Spec. Requirement: paragraph 3.5

1. Test Procedure. The method for synchronizing tapes is described in the contractor's operating instructions. It consists essentially of comparing the apparent time of arrival of a marker pulse at the slave stations against the time of transmission of the same pulse from the master station.

2. Test Results. This procedure proved cumbersome to implement even in a minimal 3-station system because of the following shortcomings:

a. It is difficult to achieve the close coordination needed among widely separated groups.

b. The marker pulse cannot be picked up in the presence of the background noise introduced by the microphones, so that the sensors must be

disconnected prior to each calibration.

    c. The markings on the Record Head Adjust dial are only approximate so that the calibration process must be repeated several times.

    d. Where large differences in tape timing occur between stations, the operator is required to align his tape by turning the zero calibrate shaft several thousand times with a screwdriver. This is quite impractical and various expedients were used to eliminate this step.

Remarks

    The method is impractical in terms of the time and effort needed to synchronize tapes under field conditions.

Timing System and Long-Term Stability

    Spec. Requirement: paragraph 3.5.

    1. Test Procedure (Described in the Appendix).

    2. Test Results. When the servo system is functioning properly, the tape will keep time with radio station WWV, without perceptible error for periods of at least several hours. Problems in the servo design relate primarily to improving reliability so that accurate timing can be achieved consistently.

Servo System and Short-Term Stability

    Specification Requirement: paragraph 3.2.1.

General

    The Servo System is intended to regulate the long-term speed varia- tions of the magnetic tape so that the numbers printed on the tape can serve as a common time reference between stations. The servo compares the phase between one 10-cps signal derived from a subharmonic of the ultrastable oscillator and a second 10-cps signal produced by optically scanning the 1/10-second timing lines on the tape as it passes under an exciter lamp. Both signals are detected in a phase comparator, and the dc output is used to apply appropriate speed corrections to the tape through a servo circuit. A panel meter permits the operator to monitor the servo action.

    The time constant of the system must be carefully chosen since too long a time constant will cause skipping of the timing lines and too short a TC will introduce short-term speed variations. In neither case will the servo correct short-term speed fluctuations originating within the equipment. The servo is an averaging device, which depends primarily on careful mechan- ical design to prevent short-term speed variations from developing, rather than attempting to correct them afterward.

1. Tape Error

The tape drive motor is a 400-cps hysteresis synchronous unit, whose speed is controlled by varying the frequency of its multivibrator type power source.

The actual drive frequency was found to drift slowly from 392 to 402 cycles with a center point of 396 cps. (See Test B for procedure in Appendix). It was theorized that the deviation from the nominal frequency of 400 cps was due to errors in tape length. Measurements of the corresponding portions of the magnetic tape confirmed this hypothesis and showed that the error in tape length conforms closely to the observed discrepancy in the driving frequency.

2. Shmitt Trigger.

To prevent variations in signal level from affecting the servo action, the amplified signal from the photoelectric cell is used to fire a Shmitt trigger, rather than passing into the phase comparator directly. In the present models it was found that the sensitivity of the Shmitt trigger had been raised to the point of self-oscillation. During warmup, oscillation occured at 22 cps. After recording started, however, this frequency "locked-in" to the 10-cps signals coming from the photoelectric cell so that the equipment was able to operate. Where, however, incoming signals fell below a threshold value, the circuit unlocked and produced timing errors. If the sensitivity of the Shmitt trigger is reduced to prevent self-oscillation, the incoming signals may be too weak to provide reliable triggering.

3. Test Procedures.
Test procedures for the measurement of short-term stability are described in the Appendix. Three different techniques are given partly to afford the test engineer a choice in meeting different test conditions and partly because the methods employed have proven applicable to the solution of test problems in other areas.

4. Test Results:
Tests A, B, and C (See Appendix).

When first received the tape speed varied continuously over a range of several percentage points. The needle of the servo meter jittered constantly indicating an unstable condition. Both long-term and short-term stability were very poor. A study of the A-3 circuit board revealed that the time constant was less than the intended design value due to normal leakage in the tantalytic capacitor which forms one element of the RC circuit. To correct this condition, a 1000 microfarad capacitor was placed directly across the low impedance output of the servo and was found to reduce speed variations, caused by the servo, to acceptable limits. While this expedient eliminated short-term speed variations generated within the servo, it is ineffective against instantaneous shifts or flicker developed within the tape drive mechanism because of momentary sticking or slippage of the tape. Test C, which is the most direct method, also shows the greatest speed variations. In extreme cases, errors of as much as 10% have been observed.

Remarks

The present servo design fails to meet minimum standards of speed control and reliability. An essential first step would be to improve tape contrast. This would correct marginal operation of the photoelectric cell arm of the servo and eliminate various design compromises in this area. A more rigorous system of controlling short-term speed variations is necessary in any future design.

Crosstalk

Spec. Requirement: paragraph 3.7.19.

1. **Test Procedure.** The test for crosstalk is described in the Appendix.

2. **Test Results.** The crosstalk for set #2 at various frequencies is given below:

Frequency	Rejection
2.5 cps	36 db
5.0 cps	36 db
7.5 cps	36 db
10.0 cps	36 db
25.0 cps	36 db
50.0 cps	30 db

Remarks

The equipment tested fails to meet the requirement for 40-db rejection of crosstalk. From a practical standpoint, a crosstalk rejection of 36 db as listed above should be tolerable under normal conditions. However, as is mentioned later under the "Dynamic Range" tests at Fort Sill, overloading at the input may give rise to a type of crosstalk which is severe enough to halt operations.

Skew Correction

Spec. Requirement: There is no formal requirement for skew correction as such; however, the need is implied in the Overall Performance Requirements, paragraph 3.8.

1. **Test Procedure** (Described in the Appendix).

2. **Test Results.** The typical error in counter readings due to tape skew is equivalent to $\pm$ 4 milliseconds. This would contribute a significant error in azimuthal determination.

Response Matching
Spec. Requirement: paragraph 3.7.1.3.

1. Test Procedure (Described in the Appendix).

2. Test Results. The equipment meets the requirement for uniformity of frequency response among the four input channels.

Frequency Response

Spec. Requirement: paragraph 3.4.1.

1. Test Procedure. The test procedure is essentially the same as that described for Response Matching in the Appendix, except for an increased number of test points.

2. Test Results. A typical frequency response curve is shown in Fig. 1. This shows marked irregularities at the lower frequencies and also that the AN/TNS-5 does not meet specification requirements above 50 cps. Poor high-frequency response would reduce the ability of this equipment to range on mortar firings.

Dynamic Range

Spec. Requirement: paragraph 3.7.1.4.

1. Test Procedure (Described in the Appendix).

2. Test Results. Results are shown in the chart below. This test shows that the equipment does not meet the specifications for dynamic range by a factor of 6 db in the case of sets #1 and #2, and by 12 db in the case of set #3.

	#1	#2	#3
1-100 cps Dynamic Range	42 db	42 db	36 db
7.5-100 cps Dynamic Range	54 db	54 db	48 db

Remarks

This deviation from specification is not serious when it is contained within the above limits. However, from time to time, serious brush noise developed which necessitated the cleaning or replacement of the brushes. Brush maintenance is a difficult and time-consuming procedure, which should be minimized in any future design.

Power Supply

Spec. Requirement: paragraph 3.1.6C.

In normal operation AN/TNS-5 is powered by two BB-424/U, 24-volt nickel cadmium batteries. One of these is in use; the other is on standby. Batteries may be switched without interrupting operation. This feature is

important in maintaining time synchronization between azimuth stations.

Nickel cadmium batteries can be charged either from a constant voltage or a constant current source and will accept very high charge rates without damage. On constant current, the total charge for BB-424/U is 34 ampere-hours. On constant voltage, a 29.5-volt potential is applied across the battery until the output current tapers off. Each battery is intended to supply 4 hours of continuous operation and under favorable conditions will actually do so. However, in practice, the batteries must occasionally be recycled by means of a slow discharge to revitalize the cells.

Power Drain

Current drains for the AN/TNS-5 under various operating conditions using a 25-volt battery supply are listed below:

a. Junction Box switch and Master switch on Tape
    Transport both in "Off" Position   = 0 amps

b. Junction Box switch "On"; Master swtch "Off"   = 0.4 amps

c. Same as previous, except Master switch "On"   = 3.3 amps

d. Same as previous, except Record switch "On"   = 3.8 amps

e. Same as previous, except Playback switch "On"   = 4.6 amps

f. Same as previous, except Computer Button pressed
    with Bridge balanced   = 4.9 amps

g. Same as "e" except Computer in full operation   = 5.2 amps

Running Life

The figures below represent a battery discharge cycle across a 6.3-ohm resistive load. The battery had been discharged twice over 24-hour periods prior to test. It had then been recharged overnight by the constant voltage method using a maximum charge rate of 22 amps.

Elapsed Time (minutes)	BB-424/U Voltage (volts)
0	26
15	25
30	24.5
45	24.45
60	24.2
75	24.1
90	24.1

11

105	24.0
120 (2 hrs)	24.0
135	24.0
150	24.0
180	23.8
210	23.6
225	23.3
240 (4 hrs)	23.2
255	23.15
270	23.1
305	22.8
315	22.6
325	22.4

Voltage Operating Limits

The contractor has set the voltage range for the equipment at 22.5-26.5 volts. Experience shows the need for extending these limits in both directions. During constant current charging, for example, the battery potential may rise to a peak of 32 volts. While this value declines after the charger is removed, it must be expected that AN/TNS-5 will occasionally be subjected to excessive voltages. The circuitry must, therefore, be capable of surviving a maximum overload and, if possible, to continue operating.

At the low end, a weak battery manifests itself by an upward drifting of the traces on the oscilloscope. A trained operator also will recognize changes in the level of the servo meter reading as the battery voltage declines. Neither of these methods is satisfactory, however, since they require undue attention on the part of the operator. During field tests, often the first indication of battery failure would be a stoppage of the playback motor or a dimming of the pilot lights. By the time this occurs, tape synchronization will have been lost and the station must be rezeroed with the rest of the system. To give the operator greater latitude it would be desirable to have the equipment operable down to 19 volts. This is considered to be the nominal end life of the BB-424/U. Even better would be a positive warning system which would signal the need for a battery switchover.

Analog Computer

Spec. Requirement: paragraph 3.6.1.

The analog computer provides a solution to the equation

$$\theta = \tan^{-1} \frac{T_{2,4}}{T_{1,3}} \ .$$

12

Secondly, it computes the sound ranging correction in accordance with:

$$SRC = \frac{\sqrt{T_{2,4}^2 + T_{1,3}^2}}{K}.$$

Where K=Time for the signal to traverse the longest dimension of the array.

The azimuthal determination is made by balancing a bridge which includes a precision potentiometer inside the tape transport as one of its arms. This potentiometer is mechanically coupled to the counter controls so that the azimuth is an analog of the knob position. The output reading is read directly in mils. A bearing correction knob on the computer permits the operator to apply a fixed correction which automatically compensates for any rotation of the array away from grid north.

The present design is an outgrowth of a prototype model developed in part by Frankford Arsenal for the AN/TNS-5. There has been some tightening of tolerances along with other refinements in the RCA version, but in general the computer closely follows the original design. The desirable features of the earlier model are retained in the engineering test models along with some notable deficiencies.

1. **Test Procedures.** In evaluating the computer at USASRDL, major emphasis was placed upon accuracy. Two principal series of tests were performed, see Appendix.

2. **Test Results.** The test data that follow represent optimum calibration curves. Errors given below are absolute values.

Computer #1 Test "A"

Quadrant	Max. Error	Min. Error	Average Error
I	1.8 mils	0 mils	0.5 mils
II	3.5	0.2	1.9
III	4.3	0	1.9
IV	3.0	0.3	1.6

Computer #2 Test "A"

I	1.7	0	0.55
II	1.6	0	0.57
III	2.7	0.2	0.92
IV	3.8	0.2	1.50

Computer #3 Test "A"

I	1.4	0	0.13
II	3.4	0	0.73
III	1.3	0	0.70
IV	2.0	0	0.71

Analysis of Test Results

1. **Test Results - Test A.** The above figures show the performance of the computer under optimum conditions where it was divorced from external elements which might introduce significant errors. It will be seen that in all three computers, the average error in the first quadrant is within about $\frac{1}{2}$ mil and in no case does it climb as high as 2 mils of azimuth. The performance in the first quadrant is a favorable indication inasmuch as readings in the other quadrants are derived by fixed displacements from the first. The average errors for all quadrants in Computer #3 all fall within one mil although there is one excursion of 3.4 mils.

On the basis of these figures it is reasonable to expect that with further refinement, the errors due to the computer alone can be contained within one-mil limits although these figures would apply only under laboratory conditions. Extraneous sources of error in any practical test must include variations in tape speed, skew, improper signal alignment, backlash, static friction, temperature, differences in operating technique. Many of these are considered under the following discussion of test "B".

2. **Test Results- Test B.** The figures appearing below are representative. Only the first quadrant results are given, since this serves as a base for the other quadrants.

Test "B"

Quadrant	Max. Error	Min. Error	Average Error
I	6.4	0	2.9 mils

Computer #2 Test "B"

Quadrant	Max. Error	Min. Error	Average Error
I	4.8	0	1.3

Computer #3 Test "B"

Quadrant	Max. Error	Min. Error	Average Error
I	1.8	0	1.4
		Average error	1.9 mils

The above figures show a contribution by all the variables mentioned previously, although the computer error remains the principal offender.

Design Problems

Static friction is the principal source of error in the computer. Because of this, the servo system frequently fails to respond to small imbalances in the sensing bridge so that backlash and differences in operating technique affect the readings. It is possible to increase servo sensitivity by means of a simple circuit modification. However, this solution is thwarted by variations in friction over the dial range. An increase in sensitivity that is just sufficient to overcome static friction at one portion of the scale will cause dial bounce and hunting elsewhere. This problem

is not of an inherent nature. It seems likely that even moderate attention to this question in the future should result in its complete elimination.

Calibration Procedures

The recommended procedure for calibrating the computer proved to be difficult and time consuming, without providing the desired results. Although rule-of-thumb procedures were gradually evolved to alleviate the problem, the time element remains excessive. Under the best conditions, an experienced operator working with an assistant will still require about 45 minutes to calibrate the computer. The allowable time interval between recalibrations is dependent on many variables. As a minimum, however, the calibration should be rechecked once a week in the field or whenever adjustments are made in the counter settings; also, whenever the equipment is moved to a new location.

Human Engineering Problems

The difficulties in operating and calibrating the computer, stem in part from the neglect of a good human engineering practices. For example, although the calibration potentiometers are the only adjustments available to the operator, they have been assigned the following notations, (listed in order of adjustment): R-64, R-40, R-43, R-67, R-74, R-71, R-39, R-35. A logical numbering sequence based upon the circuit functions or the tuning order of the potentiometers would have eliminated constant reference to an instruction sheet.

Further confusion results from the fact that in some potentiometers, a clock-wise rotation will shift the output reading in an upward direction while in other potentiometers it gives a negative correction. Some of the potentiometers require 3 or 4 turns to affect the output readings appreciably whereas others respond to the slightest touch.

There are some nine different calibration points. At each point the operator must temporarily memorize a considerable mass of data in order to perform the required operation. The strain of retaining this diverse information while performing mental computations unduly complicates what should be a relatively simple process.

Elimination of the Computer

The difficulties experienced with the computer suggest the desirability of eliminating this panel entirely. It is noted that the counter readings on the tape transport bear a simple relationship to the computed azimuth. The digital computer which was supplied as a separate item for these tests might, therefore, readily be adapted to compute the azimuths, in addition to sorting them out. The only change in the operating technique would be to have the station operators transmit counter readings instead of azimuths to the sound central. There do not appear to be any important disadvantages to this plan. If conditions arose where it might become desirable to have the station operators compute the azimuths, they could be supplied with nomograms, which would do a job equivalent to the analog computer at a

considerable saving in cost and complexity.

Human Engineering

Spec. Requirement: paragraph 3.17.

Human Engineering is especially important in the case of sound-ranging equipment because of the more active participation on the part of the operator. This inherent limitation should have made human engineering a major objective in the AN/TNS-5 design. However, despite some effort in this direction, the disregard of good human engineering practices is one of the more conspicuous weaknesses in the present models. To cite a few examples:

1. Tape Transport Controls

The controls that govern the physical positioning of the recording medium are touchy and difficult to operate. Detent action, where used, is weak and indefinite. Excessive torque is needed to turn the Speed Selector. It is difficult to engage the Tape Adjust Knobs and this step usually results in a premature release of the tape tension switch which consequently pulls the signals off the screen. Because of this balkiness in the Tape Adjust controls, the less convenient Speed Selector must normally be used to bring signals into range.

2. Oscilloscope Controls

The four signal traces on the scope are stacked vertically. By contrast, their associated controls are arranged in a horizontal row. The operator must, therefore, constantly bear in mind that the traces are to be adjusted not by reading the controls 1-2-3-4 from top to bottom but 1-3-2-4 reading from left to right.

3. Electrical Hazard

The framework of AN/TNS-5 is "hot" with respect to ground. In damp weather, the operator touching the metallic portions of the equipment receives an uncomfortable shock.

4. Eyepiece

A heavy connecting cable droops over the eyepiece of the record head, preventing the operator from bringing his eye up close to the glass.

5. Vernier Dial

The playback head is equipped with a vernier dial which is intended to permit a time readout of the tape to within 0.01 seconds. However, the gap between the dial and the printed surface is so large that parallax and glare make accurate readings impossible and this device is unable to serve its intended purpose.

6. Optical System

The optical system includes a prism and a fixed focus lens to assist in reading the tape markings. Persons who have difficulty in accommodating their vision to nearby objects (presbyopia) find the numbers blurred.

A means of focusing the lens should be provided to compensate for differences in visual acuity.

7. Master Switch

No master switch is provided. To shut down the equipment completely, the operator removes one of the batteries and flips the battery switch on the junction box to the position held by the evacuated battery. This is inconvenient and may result in battery failure when the operator overlooks this step.

8. Counter Numbering System

The counter units are numbered from 0 to 2000 with the number "1000" representing a midpoint in time. Counter readings above 1000 indicate that the sound has arrived first at the number 1 and 2 mikes, while counter readings below 1000 denote the arrival first at the number 3 and 4 mikes. Student operators find it difficult to grasp the concept of a zero reference which is equal to 1000; in this respect, an important insight is lost. A better approach to the counter numbering problem would be a 1000-0-1000 numbering system printed in two colors to indicate positive and negative values.

9. Zero Time Calibration Potentiometers

The potentiometers used for setting the counters on zero are mounted inside the oscilloscope. These must be adjusted at least once a day during normal use and the operator must remove the scope from its cabinet each time this step is performed. Illogically, other potentiometers, which were never used, are mounted conveniently on the front panel. This arrangement should, of course, be reversed in any future design.

10. Screen Persistence

A medium persistence P-1 phosphor is used for the screen in the oscilloscope. As a result of the low sweep rate there is a disturbing flicker. Since the contractor's choice of phosphors is merely a first approximation to the optimum value, further study along this line should prove rewarding.

11. Analog Computer

Human engineering factors relating to the computer are considered separately in the section dealing with this equipment.

Human 'ngineering-Maintenance Aspects

Servicing the oscilloscope is a relatively simple procedure. To assist in field maintenance, a majority of the circuitry has been built on printed circuit boards of the plug-in type. (Spec. para 3.10.) While all of the boards on any chassis are of the same general design, appropriate keyways prevent accidental insertion of any board in the wrong socket. Printed circuit boards in the oscilloscope are readily accessible by unfastening four panel screws and drawing the chassis forward on a set of metal slides. Spring locks prevent the operator from pulling the unit onto the floor.

By way of contrast, gaining access to the printed circuitry to the Tape Transport is a major operation normally requiring the services of two men. Some 51 (!) different screws must be loosened, the tape unthreaded, the tape bin dropped, and the heavy unit then lifted out of its cabinet and placed on the worktable in a backwards position. After replacing the defective board, the tape transport is reassembled by a reversal of the above process.

1. Computer Cable

Opposite ends of the connecting cable between the tape transport and computer are mismated, thus: Lead "A" at the top end may be terminated as Lead "P" at the lower end, while Lead "P" at the top end may become Lead "Z" at the computer. This inconsistency imposes an unnecessary burden on the maintenance man.

2. Trigger Head Mountings

The trigger heads are tubular in shape with a flat on one side to prevent turning in the mounting. In the AN/TNS-5, however, the trigger heads are mounted in perfectly round holes. The heads are secured by set-screws which are tightened not against the flat edge but rather against the round edge of the tubule. This is not only poor workmanship, but may lead to improper orientation of the heads after replacement or adjustment.

3. Microphones

The microphones are easily disassembled for servicing or inspection by unscrewing similar caps at either end. Removing the lower one, however, automatically destroys a delicate factory adjustment and renders the mike unserviceable in the field. Since the contractor has taken no precautions against such an occurrence, there is a 50-50 possibility of unscrewing the wrong cap. Routine examination may, therefore, seriously damage the microphone. Adding to the possibility of accidental destruction of the RCA microphone is its cylindrical shape. Since it cannot conveniently be stood on end for storage, the microphone must normally rest on its side. If the worktable is slightly tilted, the microphone will fall to the floor. Constant vigilance is necessary to prevent this.

Reliability

The dominant problem in testing the AN/TNS-5 is in maintaining operation despite incessant breakdowns. The constant interruptions for servicing delayed testing made advance planning almost impossible. While reliability is scarcely characteristic of any new equipment, the AN/TNS-5 fell below minimum standards in this regard. Both electrical and mechanical weaknesses contributed to the heavy list of failures. For example, an analysis of 27 third or higher echelon repairs listed as "Loss of Horizontal Traces" shows 15 different causative factors. Of these, three are mechanical in origin while 12 are electrical.

Electrical breakdowns predominated in the laboratory, while mechanical failures become more prominent at Fort Sill. This difference stems in part from the cumulative mechanical wear after a few hundred hours of running time and partly from the effects of ambient heat and dust on equipment that did not have an inner dust cover. Mechanical failures in the field are apt to be particularly troublesome because of the lack of suitable spare parts, and difficulties in installation.

Another serious aspect of the reliability problem is the seeming ability of defective equipment to continue operating in the presence of hidden breakdowns. On several occasions, apparently good equipment was found to be turning out readings that were several hundred mils off target. In less-experienced hands, these errors might have continued indefinitely.

Remarks

The excessive number of malfunctions experienced in the AN/TNS-5 arise from several sources.

1. The equipment is basically of a complex nature. The statistical probability of failure, therefore, weighs heavily against the possibility of five AN/TNS-5 equipments working simultaneously along with their data links, power generator, and digital computer. To meet the problem at Fort Sill, three RCA engineers, each one a specialist in some phase of the AN/TNS-5, were constantly on call. Despite this added assistance, reliability continued to be a problem. Toward the end of tests, two of the sets failed, when drive gears wore out, and they were returned to the laboratory in an inoperative condition.

2. Manufacturing tolerances of certain mechanical assemblies were tightened unrealistically in a "brute force" approach to the accuracy problem. Some tolerances had not been met when the equipment was shipped from RCA and were degraded further by shock, vibration, and wear during tests.

3. Inadequate in-plant testing left the AN/TNS-5 with many latent defects which first came to light after delivery. This was particularly noticeable with respect to factors relating to accuracy such as short-term speed variations, skew, servo stability, and computer accuracy.

4. Marginal design and components resulted in circuitry with insufficient reserve to compensate for wear and tear or for normal variations in manufacturing tolerances, environment and voltage.

Workmanship

Spec. Requirement: paragraph 3.18.

Test Procedure. Visual Inspection plus Field Experience.

Workmanship is average despite some severe lapses which downgrade performance and reliability. To cite a few examples:

1. At the end of their rotation, movement of the counter controls is halted by pulling on the lead wires which connect them to the trigger heads. Inevitably these broke after some use.

2. The Speed Selector knob is not secured and may fail to engage properly after the face plate is removed.

3. Color coding is different in all three sets. Some thick multi-wire cables in the Tape Transport were not color coded at all.

4. Mounting cases are not interchangeable.

5. The excessive number of wires going into certain of the plugs and jacks greatly impedes servicing. Division into three or four separate cable runs during construction would have avoided this problem.

6. The outer wrappings on the external connecting cables are not properly secured so that they break away at the plugs.

7. Although precision gears are used consistently throughout the tape transport, the contractor neglected to provide a protective dust cover for the gear assembly. This oversight was the cause of numerous mechanical failures at Fort Sill.

Environmental and Shock Tests

Destructive testing was postponed until the performance characteristics of the AN/TNS-5 could be fully evaluated. It is intended that supplementary testing will take place at USAERADL in the near future. A separate report will be issued upon completion of the final tests.

FIELD TESTS

Field tests were performed on engineering-test models of the AN/TNS-5 at Fort Sill, Oklahoma, during the period 14 August - 7 December 1961.

Positioning of Equipment

The ability of the AN/TNS-5 to operate on uneven ground was checked because of possible tape-tracking problems. Tests were conducted in various locations where the equipment rested at a slant; results show that level ground is not essential since the equipment functioned satisfactorily in any position likely to be encountered during normal operation.

Result: Equipment positioning is not critical in AN/TNS-5 operations.

Processing Time

This test determined the time needed for a single azimuth station to process a set of signals and to report the data back to a central point.

Test Procedure

A G.I. operator was instructed to analyze all incoming signals during a period when moderate firing was occurring on the range. He recorded his data and handed the test sheet to a radio operator who was standing by. The information was transmitted by radio to a second station set up a short distance away. Here the data was again recorded, and then repeated back to the first station for confirmation. The radio operators used standard communications procedures. The AN/TNS-5 operator avoided doubtful or distorted signals and worked without interruption.

Results

During an 80-minute test period, the AN/TNS-5 operator was able to report out a total of 15 azimuths contained within a 17-minute stretch of recording tape.

A breakdown of the individual actions is as follows:

1.	Centering signal on scope, adjusting counters, and computing azimuth.	= 120 secs
2.	Recording data on pad	= 15 secs
3.	Transmitting data via radio and awaiting confirmation.	= 45 secs
	Total	= 180 secs

The 180-second figure given above omits the following intangibles which would be present in any practical operation.

1. The time consumed in finding signals to process. This depends on the volume of firings and will vary greatly.

2. The time required for operation of the digital computer, presently supplied as a separate item, at the command post.

3. Waiting time for the radio operator in the event he must await his turn when contacting the command post.

4. Transit time of one minute for passage of the recording tape in cases where it is desired to range on a specific target which has just fired.

5. Time required for the application of meteorological corrections.

Remarks

A direct comparison of processing time in the AN/TNS-5 and GR-8 is difficult because of the many variables involved. It is probable, however, that the AN/TNS-5 suffers no important disadvantage in this respect.

Dynamic Range

Spec. Requirement, paragraph 3.7.1.4.

The AN/TNS-5 is intended to handle signals without distortion over a 60-db range. Signals actually processed during the tests fell between levels of 0.04 to 5 dynes per cm, about 42 db.

The present equipment has an ultimate sensitivity of 0.01 $dyne/cm^2$. Although this is desirable, extreme sensitivity is not critical in the reception of weak signals, since wind noise seldom falls below 0.01 $dyne/cm^2$. In detecting signals, the AN/TNS-5 operator sets his amplifier gain control to some convenient average value which is determined by local conditions. For a given setting, he can sense signals over a maximum 40-db range. Signals which are appreciably weaker than this are lost or at best disregarded. At the other extreme, very strong acoustic excitation (about 20 dynes) applied to the mikes will overload the system and cause crosstalk on adjacent channels. While this problem is outside specification limits, crosstalk must be controlled in future equipment.

Remarks

On the basis of the field tests, it appears that the sensitivity of the AN/TNS-5 is in excess of requirements and could safely be reduced some 6 db. This would be advantageous in moderating some of the more difficult technical requirements and result in greater simplicity and reliability in the end design. The dynamic range should be expanded to accommodate signals at the 20-dyne level.

Audio Monitor

The AN/TNS-5 is equipped with an audio monitoring device to relieve the operator from the strain of continuously watching the oscilloscope. The monitored sound is heard some seconds before the signal appears on the screen.

Since playback occurs at 160 times the recording speed, the frequency of the incoming signals is multiplied proportionately. Signals recorded at 1-100 cycles are played back at 160 to 16,000 cps. A headset is supplied with the equipment.

Test Procedure

A test was performed on September 22, 1961 to determine the ability of the operator to pick up artillery firings and to differentiate them from wind noise. The operator listened to the incoming signals while seated with his back to the equipment. When he sensed a signal he raised his hand, and a second operator who was watching the scope, judged whether or not it was a valid alert. Wind velocity was between 12 and 23 mph.

Result

At the start of the test the number of errors was large; however, as the audio operator gained experience, his accuracy improved, and eventually it became difficult to say which operator was in error. The sensitivity of the audio and visual monitoring systems is comparable for weak signals. The operator's headset is fitted with large rubber cups to exclude outside noise. The wearer soon complained of discomfort and apparently resented the feeling of isolation from the group.

Remarks

Audio monitoring is a practical means of detecting incoming signals. It will find its greatest application in quiet sectors of the battlefront under favorable sound-ranging conditions. A loudspeaker is necessary in future equipment to gain maximum benefit from this device.

Signal Filters

A key feature of the AN/TNS-5 is the selective electronic audio filters built into the oscilloscope. These permit the operator to adjust the band-width of the incoming signals in accordance with local noise conditions. It was found that as the operators gained experience, the 7.5- to 10-cps range became the preferred setting. Although this band is considerably narrower than commonly used in sound-ranging, the practice of restricting bandwidth to the lower frequencies permitted the analysis of signals that would other-wise have been lost in noise. This improvement probably results from the fact that signals are overlayed in the AN/TNS-5, whereas only the leading portion of the wave is used in GR-8 analysis. In addition the signal-to-noise ratio improves with decreasing bandwidth.

Unfortunately, the filter switching arrangement did not permit investigations at still lower ranges. It seems possible that further improvements in signal to noise might have resulted from tests conducted at 3-to 7.5-cps, or even lower, frequencies.

Power Supply

The AN/TNS-5 is powered by a single 24-volt nickel cadmium battery, BB-424/U. Under laboratory conditions this unit was found to be capable of providing 4-4½ hours of continuous operation. In the field, however, this figure was seldom achieved, and battery failures occurred at unexpected and inconvenient times. Moreover, continually carrying the heavy batteries between test van and battery shop proved to be an arduous task.

The PP-1658 battery chargers furnished by USASRDL were capable of recharging the batteries in less than an hour. At their maximum charging rate, however, the rectifier units consistently overloaded the commercial power lines and proved useful only when driven by a high output engine-generator such as PE-95. A stopgap solution was achieved by floating the AN/TNS-5 batteries across the dc charger and replacing only the current actually consumed. This expedient made it possible to use a smaller engine generator such as PE-75. It is important to note that although both the PE-75 and PE-95 have uncomfortably high noise levels, they do not introduce acoustic interference even when installed in the vicinity of one of the microphones.

Remarks

It is believed that future equipment should embody one of the newer sound-suppressed, low-voltage, gasoline-driven, dc generators now being developed. A smaller battery could then be employed, working only on a standby basis. In addition to minimizing the battery problem, a gasoline engine-generator would encourage the development of better equipment by relieving the set-designer of unrealistic power requirements.

Microphones

The microphones are of the capacitor type and derive dc power entirely from the junction box of the AN/TNS-5. The microphone is not polarized and the wires may be connected without reference to battery polarity. These units were originally designed to be coupled to the junction box through a 3-wire cable, but were subsequently converted to a 2-wire system. The 2-wire modification was evolved at a late stage in the development and because of space limitations, the additional circuitry was mounted externally by clamping the printed circuit boards in pressure terminals originally intended to hold the 3-wire lines. To prevent corrosion, the external structure was covered by a Conformal plastic coating. This expedient was not entirely successful; in a few cases, microphone failure occurred where moisture appeared under the terminals. This is not considered a serious defect since the solution is self-evident.

Frequency Response

Frequency response curves supplied by RCA show a relatively flat response for their microphone from 0.1 to 200 cps. By comparison the T-23 microphone with a 25-cps acoustic plug covers the range (3 db points) from 5-25 cps. Some apprehension was felt that the extended response of the RCA mike might cause overloading of the system by extraneous noise, and an effort was made to preclude this possibility by installing adjustable air leaks on four microphones. These permitted an optional cutoff of frequencies below 5 cps.

Field tests, however, failed to show any discernible difference in the performance of the modified and unmodified RCA mikes and they were used interchangeably throughout the tests.

Water Resistance

Water absorption proved to be the major problem in the new microphones. During operations they are suspended from a BE-66/A cover over a hole in the ground. When rainwater seeps into the hole, it readily penetrates the mike and attacks the sensitive aluminum diaphragm inside. Since the aluminum coating is only a few microns thick, it is quickly destroyed in the resulting chemical reaction.

It is to be noted that microphone T-23 is also vulnerable to water immersion. In the case of the T-23, however, the sensing element is platinum wire which resists corrosion so that operations may be resumed as soon as the microphone dries out. Another factor in favor of the T-23 is the placement of the output terminals and air leak at the top of the case. Water would have to rise almost to ground level before it affected the T-23. In the RCA mikes, the terminals are at the bottom where they are readily shorted out by water even if the microphone itself is not damaged.

Remarks

Although serious, the shortcomings described above are not of a fundamental nature and can be readily corrected through a better selection of diaphragm coating materials and by a rearrangement of the output terminals. In this case the RCA mike might be the choice for many sound-ranging problems other than the AN/TNS-5. Its advantages lie in its freedom from polarity problems, its low power requirements, broader frequency response, greater compactness, and elimination of an internal battery supply.

Personnel Training

No formal program was organized during the test period. New operators were given an hour or two of intensive instruction. This was followed by informal discussions of specific problems as the need arose. Student operators readily learned the functions of the various controls and were soon getting excellent results. Sound-ranging experience proved more valuable in operating the AN/TNS-5 than a prior knowledge of electronics.

Remarks

There should be no problem in retraining sound-ranging personnel to operate AN/TNS-5. Two or three hours per day of instruction continued over a one-week period should convert a good GR-8 man into a first-class AN/TNS-5 operator.

Spurious Response and Signal Identification

A type of spurious response was noted in the AN/TNS-5 which is apparently peculiar to the present equipment. When a transient is fed into the front end, it will be found that upon playback the signal will be bracketed by a miniature replica of the parent response. This is shown below.

Where two or more transients occur, as is commonly the case in sound ranging, additional spurious responses will be generated.

When the train of pulses is sufficiently prolonged, the spurious signals infringe upon the "first break" causing it to become obscured. Because of this anomaly, the breaks in the AN/TNS-5 are generally inferior to those of the GR-8 for signals of corresponding quality measured at an equivalent bandwidth. A marked degree of uncertainty results from this, particularly in cases where the operator falls into the error of sound-ranging on the "phantom" signals. The greater proportion of gross errors appearing among the AN/TNS-5 data may be indicative of these spurious responses. The cause of this type of response was not fully determined at the time this report was prepared. However, available evidence points to some sort of "end effect" in the record head, which results in leakage of magnetic flux on either side of the main slit.

Accuracy Test - Sound Ranging Set GR-8 Vs. AN/TNS-5

Test Procedure

The two systems were set up in parallel along Bald Ridge. The three AN/TNS-5 square arrays were interleaved with the six GR-8 microphones to provide azimuths corresponding to the 1, 3, and 5 rays of the T-23 microphones. Three hundred meter square arrays were used. These were rotated 1600 mils from grid north to avoid local obstacles.

Two AN/TNS-5 sets, #2 and #3, were installed in the M-109 van in which
they were shipped from USASRDL, and a third set was installed in a separate
van furnished by the Artillery Board. The GR-8 equipment operated from its
own van.

The three vans were driven to a spot approximately at the center of the
base line and all comparison tests were conducted from this location. TNT
demolition charges, ordinarily 10 lbs in size, were detonated from various
Firing Points on the range. A 5-second countdown was given immediately prior
to each firing to alert operators in all vans to the arrival of the signal
and to prevent confusion with extraneous signals. A meteorological team
supplied a visual meteorological message at 1-hour intervals. Coordinates
of all targets were accurately known and were made available to the
operators. This was done to avoid ranging on unwanted signals and to weed
out any equipments in which unrecognized breakdowns might have occurred.
However, since the operators were unable to add the meteorological
corrections until after the azimuths were recorded, deliberate "cheating"
was discouraged.

Results

In about half of the tests, one of the three AN/TNS-5 stations broke
down prior to, or during the course of the test, and a comparison with the
GR-8 was limited to only two rays.

A full analysis on the basis of radial error is, therefore, impractical.
However, since the radial error is a function of the azimuthal error, a use-
ful comparison is possible by referring to the more fundamental unit when
more complete data is unavailable.

Average values using approximately 150-azimuth readings from each set
showed the following errors:

$$GR-8 = 10.2 \text{ mils} \qquad\qquad AN/TNS-5 = 11.8 \text{ mils.}$$

These show a margin in favor of the GR-8.

Although the GR-8 equipment had the advantage of experienced operators,
this was not a major factor since some of the earliest tests showed best
results for the AN/TNS-5.

Probably the best explanation for the slightly poorer performance of
the AN/TNS-5 stems from errors introduced by weakness in the signal breaks.
This problem is discussed elsewhere in this report.

Evidence of mismating signals is shown by the occasional appearance
of gross errors in the midst of good readings. These degrade the averages.
If all azimuths showing an error greater than 30 mils are removed from both
the GR-8 and AN/TNS-5 data and the averages recomputed, the following errors
result:

GR-8 = 9.9 mils   AN/TNS-5 = 10.6 mils.

The improved figures are the result of dropping 2 azimuths from the
GR-8 data and 5 azimuths from the AN/TNS-5 data.

In two series of firings where all sets were operating and the radial
error was computed, the GR-8 retained its advantage.

Date	Number of Firings	Average TNS-5 Error Using Computer	Average TNS-5 Error Using Counters	Average GR-8 Error
30 Aug 61	9	132 meters	126 meters	93 meters
2 Oct 61	14	168 meters	----	135 meters

The better averages for the 30 August 1961 figures above are due to
poor meteorological conditions during the October 1961 measurements.

Remarks

The GR-8 enjoyed a minor advantage over the AN/TNS-5 in accuracy. This
is because of the recognized shortcomings in the present models rather than
to any inherent deficiency. A fully engineered AN/TNS-5 with a clean signal
response, accurate computer, stabilized tape speed, larger scope tube, etc.,
should compare favorably with the GR-8 in accuracy.

Target Range

Test Procedure

Various sizes of TNT charges were set off at target ranges of
3,000-11,000 meters. No direct relationship was found between target range
and the quality or level of the received signals. In all cases meteorolo-
gical conditions were the controlling factor in determining the distances
over which useful signals could be received.

Note: The GR-8 and the AN/TNS-5 performed equally well in this test.

Array-Size-Accuracy Comparison

Test Procedure

The AN/TNS-5 sets were up at Station 37 on the East Range. The equip-
ment was installed at the center of four concentric arrays. Ten-pound TNT
charges were set off at various firing points and the resulting signals were
measured simultaneously on two or more sets.

Array-size comparisions were usually reserved for days when only two
sets were operating. The 150 and 600-meter arrays were used to emphasize
contrasts due to differences in size. The number of firings per test is

only approximate since readings were occasionally lost or discarded for one reason or another. Azimuths that showed obvious errors were rejected immediately and are not included in the following compilations.

As an additional refinement, a second table of averages is shown in which all errors of 25 mils or over have been omitted.

All azimuths were recalculated on the basis of counter readings in order to eliminate any error contributed by the analog computer.

Date (1961)	Approx. No. of Firings	Average Error (in mils)			
		50-m Array	150-m Array	300-m Array	600-m Array
Sept 7	3	-	20	-	7
Sept 14	10	-	11.5	-	10
Sept 19	11	-	9.2	-	6.4
Sept 21	5	-	6.6	-	17.2
Oct 3	8	6.0	10.0	9.0	-

Average Errors for All Firings

50-meter arrays = 6 mils
150 -meter arrays = 10.5 mils
300-meter arrays = 9.0 mils
600-meter arrays = 9.5 mils

Average Errors Omitting Azimuths with Over 25-mil errors

50-meter arrays = 6 mils
150-meter arrays = 7.3 mils
300-meter arrays = 9.0 mils
600-meter arrays = 6.7 mils

Remarks

A comparison of the 150-and 600-meter arrays for which the data is most complete shows an advantage in accuracy of 0.6 - 1.0 mils for the larger array.

It is probable that in a larger sampling the 300-meter average error would fall in between these two values, and that the 50-meter average would be rather poorer than it is.

The effect of using counter azimuth* rather than those from the analog computer has considerable bearing on the above figures since the expected computer error rises sharply for a small array.

The average computer error for various size arrays appears below. These statistics are drawn from a much larger population that the previous table and may be considered as representative.

Size of Array	Average Error
600 meters	1.6 mils
300	1.8
150	3.4
50	7.4

The above tests show no marked advantages in favor of the largest arrays. This seeming contradiction results from two competing processes.

In one case, corrugations in the wave front degrade the accuracy of the small array, whereas differences in sound velocity are more troublesome for large arrays.

The choice of array size must, therefore, be determined in each case by meteorological conditions, and the tactical situation.

Mass Firing Test

Test Procedure

Two series of mass firings were carried out on September 28 and October 5, 1961.

In the first series, six guns were fired in the following sequence:
First Shot - one round, all guns in unison.
Second Shot - one round, in unison, second round rapid fire.
Third Shot - one round in unison, second and third round rapid fire.
Test firings began at 20:30 hours at which time meteorological conditions were assumed to have stabilized. The second and third shots followed at one-hour intervals. The waiting interval between shots was used by the AN/TNS-5 operators to analyze the data.

The disposition of the targets was considered unsatisfactory during the Sept 28 firings because of limited dispersion which resulted, in one instance, in having two guns directly in line behind one another.

---

*"Counter azimuths" are pencil and paper calculations based upon the Veeder-Root Counter readings which appear on the face of the tape transport. "Counter azimuths" are more accurate that "Computer azimuths" which are derived from the analog computer supplied with the equipment.

In the second series of firings carried out on Oct 5, two of the guns were omitted and the shots took place in the following sequence:

Shot 1 - one round in unison, one round rapid fire.
Shot 2 - one round in unison, two rounds rapid fire.
Shot 3 - one round in unison, three rounds rapid fire.

In both series of tests, the magnetic tapes on the TNS-5 were synchronized immediately prior to the firings to minimize timing errors.

One meterological message was supplied for each firing.

The GR-8 operators were alerted to the incoming signals by a "forward observer."

Target Coordinates

	E	N
FP 338	62058	33654
FP 340	62373	32956
FP 341*	62768	32991
FP 526*	63394	33173
FP 527	62697	33304
SAA 8	63390	33304

* Not used in Oct. 5 tests.

Coordinates for Center Point of TNS-5 Arrays

	E	N
Set #3	63944	38811
Set #2	61251	39020
Set #1	58559	39228

Computer

For purposes of processing the TNS-5 mass-firing data, an Autonetics Co. "Repac" computer was shipped from Fort Monmouth and preliminary analyses were made on the scene. Although this computer is relatively slow by present-day standards and is not of military quality, it is nonetheless capable of supplying useful data.

General

Prior to development of the AN/TNS-5, the mass of data resulting from a problem of this type imposed a severe strain on the ingenuity of the human operator who had to find related groups of signals which might later yield the target locations. In the GR-8, this is necessarily a process of

31

trial and error which due to the large number of variables quickly becomes unmanageable. By contrast, the square array of the AN/TNS-5 offers an inherent advantage in meeting this problem. For one thing, incoming signals will pass over a 300-meter array in less than one second so that the tape analyst can disregard responses falling outside this relatively narrow time interval. Where signals from multiple targets do occur within the same one-second period, the AN/TNS-5 operator can usually match related signals by noting similarities in their waveforms. GR-8 operators are prevented from using the waveform technique to match signals because of overloading in the recorder which destroys any individuality in signal characteristics.

On the other hand, although azimuths can be obtained from each azimuth station, the validity of the intersections from all azimuth stations cannot be ascertained until further processing has taken place.

Signal Analysis is performed in the AN/TNS-5 by the "Repac" digital computer mentioned previously. This unit compares the time of arrival and azimuth from one station with equivalent data from each of the other stations in the system. When the resulting computation falls within a certain time tolerance (epsilon), the computer reads out the data in the form of the actual target coordinates.

Test Results

The volume of data resulting from the test was sufficient to overwhelm the GR-8 system completely. Despite intensive effort on the part of the GR-8 operators, no useful target locations resulted. On the other hand the AN/TNS-5 station operators were able to process their tapes without difficulty. A large number of azimuths were recorded, most of which could be identified with known targets.

On the negative side, the problem of obtaining unique locations of the targets from the time/azimuth data transmitted to the sound central proved to be beyond the system's capabilities. Neither visual examination of the computer runoff data nor of plots made of the intersections showed a unique separation of all targets. An exception was noted in the case of Target FP 338, which was clearly bracketed on most computer runoff charts. Other than this, the points of intersection were of a random character in that false target concentrations occured freely along with valid targets. Without a prior knowledge of the target locations, both groupings would be considered as true targets.

To eliminate the contribution of propagation and reading errors, the problem was rerun on a simulated basis at USAFRADL, retaining the relative positions of the AN/TNS-5 arrays and targets but computing the true values of the azimuths, target ranges, and times of arrival beforehand. The targets were again assumed to have fired at the same instant.

When however this "ideal" data was reprocessed by the sorting computer, the output readings continued to show a largely random distribution.

The difficulty arises from the large number of intersections (see Fig.2) which are generated during even short intervals when several guns fire together. The Fort Sill mass firing, for example, produced 360 intersections per round, in a full-size system. The probability that many spurious intersections will meet the acceptance criteria set up for the computer then increases to the point where a continuous spectrum of intersections appears in the readout data.

In order to eliminate all spurious locations from the final data, the overall measuring errors would have to be controlled to within a few thousandths of a second. Even with a very tight "Epsilon" of 0.25 seconds, about 40% of the locations derived from "ideal" data will prove to be spurious. While many of the false intersections can be rejected summarily, a significant proportion are indistinguishable from valid targets.

It should be emphasized that the above remarks apply only to the test conditions for the Sept. 28 and Oct. 5 firings at Fort Sill.

Under different circumstances the test results might be better or worse. If a normal complement of five, rather than three AN/TNS-5 sets had been used, the proportion of spurious locations would have been greater. The use of "live" rather than simulated data would also increase the probability of false locations. On the other hand, when the simulated problem assumes that only two (the worst of the group) rather than six guns have been fired in unison, very good data will result. If the simulated problem assumes that the targets have fired one second apart, the number of spurious locations is reduced by half and the false intersections are more widely dispersed. For an assumed two-second separation between firings from the various target points, perfectly clean target locations result.

In the last case, additional test runs were performed on the digital computer in which simulated azimuthal errors averaging 10 mils, and timing errors of 0.04 second were injected into the input data. Only minor degradation of the test results occurred in the readout data.

Remarks

The ability of the AN/TNS-5 to completely process mass firings was not established in the present tests. The failure results primarily from the selection of target points which resulted in the almost simultaneous reception at the arrays of signals coming from several sources. The AN/TNS-5 will perform effectively only when used within the limits of its capabilities. The essential conditions for ranging on multiple firings with a 3-station system require that there be a limited dispersion of targets so as to produce a tighter knit group of intersections. When this criterion is met, it is possible to range on an entire battery although individual targets would not be distinguished. Alternately, the AN/TNS-5 will handle targets providing the signals arrive at the arrays at least one to two seconds apart. While it is not expected that the enemy will cooperate in achieving these goals, the probability is that suitable conditions will occur often enough of their own accord to make the AN/TNS-5 a useful instrument.

SUMMARY OF PROPOSED MODIFICATIONS FOR AN/TNS-5

Many of the suggested modifications listed below have already appeared elsewhere in the text. They are assembled here for the reader's convenience. These proposals are based upon the RCA model and the existing system concept and should not be considered as endorsements for either in their present form. It is recognized that totally new approaches may be revealed during future developments which would obviate the need for many of the changes described here.

1. Equipment should be provided with a master power switch.

2. Vernier dial on playback position should be relocated to eliminate parallax and glare.

3. Tape contrast should be improved.

4. A safety switch should be provided to prevent damage to the recording medium in the event of a 4-hour accumulation of tape in the intermediate storage bin or in case of snags occurring in the storage bin.

5. The waiting period between the recording and playback of signals should be reduced.

6. The cause of tape snarls should be determined and steps taken to eliminate it.

7. A means for speeding up the flow of the magnetic tape should be provided to permit rapid sychronization of tapes where wide disparities in timing occur prior to startup.

8. Recording speed should be increased sufficiently to eliminate the need for special skew correction circuitry.

9. A tape threading diagram should be installed inside the front cover of tape transport.

10. Automatic data input between the tape transport and digital computer should be provided.

11. Microphones should have mounting rings or ears to facilitate mounting on wind screens.

12. Flats should be provided along edges of microphone to prevent rolling.

13. Factory adjustments in the microphone and elsewhere should be sealed to discourage unauthorized tampering.

14. The microphone power switch should be ganged with the record-motor starting relay. This would insure that the microphones were operating whenever recording was taking place.

15. Microphone amplifier should be designed to allow grounding of one side of the wire line.

16. Microphone circuitry should be completely enclosed.

17. The microphone power supply in the junction box should be capable of continuous operation in an unloaded condition.

18. The selection of materials used inside the microphone should be re-examined with a view towards improved water resistance. Connecting terminals should be brought out from the top of the mike housing.

19. BP-1 Terminals used on the microphone and junction box should be replaced with Mil-type screw-down terminals.

20. Where several wires must be accommodated by a single binding post as in the case of the telephone terminals, the size of the binding post should be increased accordingly.

In accordance with conclusions stated under the relevant laboratory tests, it is recommended that further development of the analog computer be discontinued. Items 21 thru 26 are included only for purposes of record.

21. The balance switch on the analog computer should be spring loaded so that it automatically returns to "operate" position after balancing the bridge.

22. The bearing correction knob on the computer should be provided with a locking device to prevent accidental change of settings.

23. Calibration procedure for the analog computer should be simplified in accordance with good human engineering practices.

24. Design of the manual control on the computer should be improved from the standpoint of simplifying its removal and reassembly for servicing.

25. The packaging of the analog computer should be modified to integrate it with the other major components of AN/TNS-5.

26. The computer servo should be redesigned to reduce errors due to static friction and dial bounce.

27. The gain controls on the oscilloscope should be stacked vertically corresponding to the positions of the traces on the screen.

28. The gain controls should have a "dead" position in which the trace is completely suppressed. This is valuable when only 3 microphones are operative.

29. Microphone positions should be designated as North, South, West, and East. In cases where the array has been rotated, North would be the microphone which becomes North after adjusting the bearing correction control on the computer.

30. Self-checking facilities should be built-in to the equipment so that the station operator can tell whether his set is working properly. . This should include a means for feeding a 10-cps signal from the ultrastable oscillator into the front end of the recorder.

31. The sweep circuits of the oscilloscope should be revised so that a signal which has been centered on the scope tube retains its relative position for different fields of view.

32. The choice of fields of view should be modified as follows:

4000 millisecond - true position of traces

4000 millisecond - shifted traces

1000 millisecond - shifted traces

400 millisecond - shifted traces

100 millisecond - shifted traces.

33. The intensity of the scope traces should automatically be increased on fast sweeps.

34. Longer persistence phosphors should be used in the scope tube to eliminate residual flicker. A larger tube should also be considered if available in a low power version.

35. Harmonic generators should be included in the oscilloscope to multiply the ultrastable oscillator calibrating signal from the Master Station back up to its fundamental frequency. Frequency comparison would then take place at the higher frequency.

36. The counter-zero alignment potentiometers should be brought out to the oscilloscope front panel. The trim adjust potentiometers should be moved inside the scope.

37. Marker transients generated in the Zero Time Calibrate circuit should be increased in amplitude, of the input sensitivity increased. It should be possible to synchronize tapes at the different azimuth stations without disconnecting the microphones.

38. Undesired transients, introduced by clicking of the tape tension release solenoids, should be reduced as far as possible.

39. Audio-filter ranges should be revised as follows:

High pass	Low pass
1 - 3 - 7.5 - 10 cps	7.5 - 10 - 30 - 60 cps

40. Lighting arrestors should be provided in the interest of personnel safety.

41. A voltmeter should be included to indicate the state-of-charge of battery. This could take the form of an additional multiplier on the present servo meter.

42. Cable wrappings on external connecting cables should be reinforced at the plugs to reduce breakage at these points.

43. Fuse holders should be of the indicator type.

44. A standby position should be available to minimize current drain during inactive periods.

45. The servo circuitry should be improved in the interest of reliability. Alternately, the motor speed might be stabilized to eliminate the need for a servo system entirely. This alternative implies the use of a sprocketed tape to eliminate slippage.

46. A simplified method of timing is needed in place of the present unsatisfactory printed tape. The sprocketed tape mentioned in the previous paragraph offers a means of performing this function mechanically.

47. Excessive speed excursions noted in the present equipment should be reduced. A sprocketed tape is one possible solution to this problem.

48. Counters should read 1000-0-1000 instead of 0-2000. Color coding would be used to distinguish between positive and negative values.

49. The outside of the equipment should be grounded to reduce shock hazards.

50. The mechanics of tape positioning should be reviewed to correct existing awkwardness in operation.

51. The removal and servicing of defective components in the tape transport should be simplified.

52. Triggerhead mountings should have a flat surface on one side to insure correct orientation.

53. Nonlinearities and spurious responses in the audio system should be eliminated to reduce the uncertainty in determining the first breaks in the signal.

54. More rugged mountings should be provided for the printed circuit boards in the Tape Transport.

55. Different numbering systems should be assigned to the boards in the Tape Transport and in the oscilloscope, i.e., different boards should not have the same number.

56. Power Amplifier boards A-5 and A-6 should be made interchangeable.

57. Eyepieces on the tape transport should have adjustable focus to compensate for differences in vision.

58. The "Record Adjust" control should be mechanically coupled to the record hairline.

59. Efforts should be made to reduce the number of similar components, which are carried as different items in the spare-parts group.

60. Voltage operating limits should be expanded to 19-30 volts in line with the actual voltage experienced in the field.

61. Provision should be made to accommodate the new standardized series of radio sets.

62. The use of a sound-suppressed engine generator should be considered as a primary power source. This would be supplemented by a storage battery for standby or emergency operation.

63. Size and weight should be reduced.

64. Nuvistor tubes should be replaced by transistors.

65. A dust cover should be provided for the precision gear trains, with due consideration given to the problem of lubrication in the field.

66. Time constants in the audio system should be cut down to reduce buildup time.

67. Interaction between microphones due to dc loading effects should be eliminated.

68. The number of tests points should be increased to facilitate maintenance.

COMPARISON OF SOUND RANGING SET GR-8 VS. AN/TNS-5

GR-8 Advantages	TNS-5 Advantages
1. Less complex.	1. No forward observer needed.
2. Fewer personnel	2. Direct readout of Azimuths and grid coordinates.
3. Lower cost.	3. Faster in the case of multiple targets.
4. Less power required.	4. Builtin electronic frequency filters.
5. Greater portability.	5. No curvature correction required.
6. All personnel at one location.	6. Smaller arrays.
7. Less auxiliary equipment required.	7. No chart paper to replace.
8. Faster for single targets.	8. No battery replacement in microphones.
9. More adaptable to radio-link because of intermittent operation.	9. Greater dynamic range.
10. Wider field of view.	10. Not confused by signals coming from the rear.
11. Provides permanent record.	11. Broader frequency response.
12. No sorting computer required.	12. Azimuths independent of sound velocity.
13. Greater reliability.	13. Sound-ranging baseline can be placed further forward.
14. Faster installation and shorter warmup period.	14. Provides four hours of storage time.
15. Greater security since there is no radio transmission of processed data.	15. Magnetic storage of signal permits readjustment of signal characteristics after recording.

CONCLUSIONS AND RECOMMENDATIONS

The engineering test models of AN/TNS-5 were delivered to USAERAL for evaluation at an incomplete stage of their development. As a result, they lacked the elegance, speed, accuracy, and reliability which might be expected in more fully engineered equipment.

The contractor displayed strength and assurance in the theoretical phases of the development, but proved to be relatively weak in implementing his ideas. Inattention to detail, poor "human engineering" and marginal design contributed significantly to the poor showing in laboratory and field tests.

Although these models failed to meet the more critical performance requirements, in many cases the deficiencies can be tolerated. Where more serious problems have appeared, it is likely that they can be overcome in

the future by the application of well-established engineering principles. Particular stress is needed on the problem of reliability.

Despite shortcomings mentioned in the report, the feasibility of recording artillery data on magnetic tape has now been established. The concept of the endless tape loop is basically sound. The capacitor microphone and the built in electronic frequency filters appear to be useful contributions to the art of sound ranging. The ultrastable oscillator is one of the better designs in its class.

Comparative tests at Fort Sill failed to demonstrate any decisive overall advantage for either the AN/TNS-5 or GR-8. Each equipment has essential features which are lacking in the other. It remains to be determined whether the gains offered by the AN/TNS-5 are commensurate with the cost.

Additional study is needed on the AN/TNS-5 from a system standpoint. The present operating concept is wanting in terms of manpower requirements, complexity, size, convenience and cost. Further attention must also be given to the problem of data processing.

One alternative to the present approach would be a centralized operation in which all sets are installed at a common point. In this case a thoroughgoing mechanical and electrical redesign should precede construction in order to achieve the maximum benefits from this mode of operation. Among the essential features of a centralized operation should be a multiplex transmission system which would permit the transmission of signals from each array to the sound central via a single pair of wires.

A second alternative would be a hybrid system embodying the best features of the straight and rectangular arrays. Preliminary studies in this field have been undertaken at USASRDL and initial results are encouraging. A report will be prepared when more complete data become available.

APPENDIX

DESCRIPTION OF LABORATORY TESTS

MEASUREMENT OF LONG-TERM STABILITY

Test Equipment: Collins 51 receiver.

Test Procedure

The Collins 51 receiver was tuned to Radio Station WWV. The test engineer monitored the timing tape as it flowed over the record head of the Short-Range Missile Launch Locator AN/TNS-5. When the tone signal was transmitted by WWV signifying the start of a 5-minute cycle, the tape time as read to the nearest second. The engineer then continued listening to the one-second time ticks from WWV until he had mentally synchronized the nearest 1/10-second marking on the tape against the time standard. With practice, this test method permits a time readout to about 0.05 second.

MEASUREMENT OF SHORT-TERM SPEED VARIATIONS

Test A - Tape Speed Variations

Equipment Required:

    1 - Hewlett Packard 524A Decade Frequency Counter (referred to as H.P. Counter)
    1 - One shot multivibrator (lab-built)
    1 - plug-in cathode follower (lab-built)

To perform this test, the H.P. counter is put in the "Self-check" position in which the counter counts the 100-kc signal from its built-in frequency standard. As the 100-kc signal progresses down the line, its frequency is divided by ten at each successive decade. By the time it reaches the fifth decade, its frequency has been reduced by a factor of 10^{-} and the output consists of very narrow 10-cps pulses. The fifth-decade counter unit is unplugged and a cathode follower circuit is substituted. This provides a low-impedance transformation to the one-shot multivibrator at the test position, (see Fig. 3). The multivibrator generates a 10-cps square wave having the same stability as the 100-kc frequency standard in the H.P. counter. To prevent cycling in the counter, the gating tube is removed prior to test.

Test Procedure

The four microphone inputs to the AN/TNS-5 locator are hooked up to parallel a 1500-ohm, 2-watt resistor placed across each pair of input terminals. The resistors simulate the microphones which are not used. The

10-cps signal is then recorded on all channels.

If the 1-3 and 2-4 traces are superimposed and the signals slipped back and forth by the counter controls so that signals recorded at different times can be compared, it is possible to make a very sensitive determination of speed variations based on the differences in wavelength of corresponding signals. Quantitative measurements are possible by this test. Since at 10-cps, one count on the AN/TNS-5 counters represents 2 milliseconds in time, there should be a signal coincidence at every 50 counts. This figure may vary depending on tape speed, but it should be consistent for any 4-second period.

Test B - Speed Variations Test

Equipment Required: Hewlett Packard Frequency Deviation Meter Model 500A and Sanborn 154 Recorder.

The previous method uses random samplings of the signal to measure short-term speed variations. Speed perturbations that occur at unmonitored intervals may be overlooked. Test B described below provides a method of continuous monitoring.

Test Procedure

The tape transport of the AN/TNS-5 is temporarily removed from its cabinet and test leads are hooked to the collector of the 2N174 transistors on the record power amplifier. The output signal is coupled into the H.P. frequency meter through a 0.1 microfared paper capacitor. This meter is set on a 50-cycle scale to provide maximum resolution. Since the output frequency from the record multi-vibrator is approximately 400 cps, a dc bucking voltage must be supplied to set the H.P. frequency deviation meter on center scale.

The output of the frequency meter is a dc voltage which varies as a function of the input frequency. This data is fed into the Sanborn recorder which records frequency changes as a continuous line that moves laterally on the chart. Known frequencies are fed into the deviation meter prior to the start of testing to derive a frequency curve for the Sanborn recorder.

Test C - Short-term speed variations

Equipment Required: H.P. 300 A Oscilloscope

Test C was developed as a cross check on the other two test systems. It has the advantage of providing direct measurement of the tape motion as contrasted with Test B, which assumes that tape speed necessarily coincides with changes in the frequency of the power supplied to the synchronous record motor that drives the tape.

Test Procedure

The output from the arm of the servo, which is driven from the ultra-stable oscillator, is fed into the vertical plates of the oscilloscope. The signal from the other servo arm, which is driven by the photoelectric cell, is used to trigger the horizontal sweep on the oscilloscope. If the phase relations between the two signals remain constant, the pattern on the scope should be stationary.

MEASUREMENT OF CROSSTALK

Equipment Required:

Hewlett Packard Low-Frequency Function Generator Model 202A

Hewlett Packard Oscilloscope Model 130B

Test Procedure

Resistors(1500 ohm) are placed across each of the input terminals on the junction box. A 1.2-volt signal from the function generator is fed into one of the terminals selected at random. A 50 microfarad blocking capacitor is used in series with the line. Input-signal amplitude is monitored on the H.P. oscilloscope. When the signal appears on the AN/TNS-5 oscilloscope, the Playback amplifier attenuator is adjusted to give a $\frac{1}{4}$-inch signal on the active channel, with all vernier potentiometers set at maximum. The play-back amplifier attenuator is then advanced until an equivalent signal appears on one or more of the other channels. The difference in attenuator readings is then measured and multiplied by six to give the cross-talk rejection in decibels.

MEASUREMENT OF TAPE SKEW

Test Equipment: Hewlett Packard Low-Frequency Function Generator Model 202A.

Test Procedure

Both counter units are set to 1000. Four 1500-ohm, 2-watt resistors are connected across the microphone input terminals and the record motor is started. After a five-minute warmup period, the status switch is put into the "Master" position and a series of transients are fed into the record channels by the "Zero-Time Calibrate Switch."

A continuous 10-cps signal from the H.F. function generator may be used instead.

The tape is stopped at a convenient point on playback and with the "Number of Traces" control at 1, the signals are superimposed by adjusting the positions of the 2-3 and 4 traces, using the appropriate potentiometers on the A-3 board inside the oscilloscope. The 230-millisecond field-of-view is used for final adjustment.

The record medium is then advanced some distance until a new series of transients appear. The operator turns the counter controls until the traces are again superimposed and then takes a counter readings.

The difference between the new counter reading and 1000 represents the skew error. This test should be repeated several times at different tape locations in order to arrive at some representative value.

MEASUREMENT OF UNIFORMITY OF FREQUENCY RESPONSE FOR DIFFERENT CHANNELS

Equipment Required:

Hewlett Packard Low-Frequency Function Generator Model 202A.

Hewlett Packard Oscilloscope Model 130.

Test Procedure

1. Hook inputs in parallel with a 1500-ohm, 2-watt resistor across each pair of terminals.

2. Using an H.P. function generator with a large value of blocking capacitor in series with the output, record a 25-cps signal 18 db below maximum signal level (0.4 volts rms) on all channels.

3. Monitor input-signal levels with the oscilloscope in dc position and microphone switch turned "off" temporarily while taking measurement.

4. Set all individual channel volume controls to their maximum clockwise position and adjust playback attenuator for an approximate $\frac{1}{4}$-inch signal.

5. Using drafting dividers, check to see that the absolute levels of all channels are within 3 db.

6. Record 1-, 10-, 25-, 50-, 100-, and 120-cps signals at the same level as in 2 above, using approximately 15 seconds of record time for each signal.

7. Set playback attenuator so that the deflection of the 25-cps signal in each channel is approximately $\frac{1}{4}$-inch.

8. Adjust the individual channel volume controls so that each channel has the same gain.

9. Using drafting dividers, measure the difference in scope deflection between channels for the 1-, 10-, 50-, 100-, and 120-cps signals.

MEASUREMENT OF DYNAMIC RANGE

Test Equipment: Same as for the response matching test above.

Test Procedure

1. Set playback attenuator to position 14.

2. Place filters in the 1-to 100-cps settings.

3. Residual noise should produce less than $\frac{1}{4}$-inch deflection in each channel. If not, reduce attenuator setting to give $\frac{1}{4}$-inch deflection.

4. Place filters in the 7.5- to 100-cps settings.

5. Residual noise should produce less than $\frac{1}{4}$-inch deflection in each channel. If not, adjust attenuator setting to give $\frac{1}{4}$-inch deflection.

6. Hook inputs in parallel with a 1500-ohm, 2-watt resistor across each pair of input terminals.

7. Feed 25-cps signal at 1.2-volt level (peak to peak) into input.

8. Reduce signal on playback using playback attenuator until height of signal is $\frac{1}{4}$-inch.

9. Read playback attenuator setting and subtract reading from 3 and 5 above. Minimum difference should be ten.

MEASUREMENT OF COMPUTER ACCURACY

Test A - Computer vs. Counters

Test Procedure

The correct counter readings to be expected for a given azimuth when using a 300-meter array were computed manually for each 100-mil interval between 0-6300 mils. The resulting figures were arranged to form the test chart shown below. The counter dials were then preset to the indicated figures, the computer was actuated, and a comparison was made of the resulting computer reading versus the previously determined true azimuth. Computers were recalibrated prior to each series of tests.

Test B - Signal Measuring Accuracy

Test Procedure

A precise 10-cps signal was fed into the input of the tape transport via the junction box. (See Test A, Tape Speed Variations.) The recorded traces were then shifted back and forth by means of the counter controls to produce a graduated series of alignments up to a maximum displacement of ten periods between adjacent channels. The resulting computer azimuths were then compared with the known true values which had been determined beforehand.

AN/TNS-5 TEST SHEET
AZIMUTHS COMPUTED
FOR SOUND RANGING CORRECTION = 1.000

Mils	L	R	Computer Reading
100	1497.6	1049.0	
200	1490.4	1097.6	
300	1478.5	1145.1	
400	1461.9	1191.3	
500	1441.0	1235.7	
600	1415.7	1277.8	
700	1386.5	1317.2	
800	1353.6	1353.6	
900	1317.2	1386.5	

Mils	L	R	Computer Reading
1000	1277.8	1415.7	
1100	1235.7	1441.0	
1200	1191.3	1461.9	
1300	1145.1	1478.5	
1400	1097.6	1490.4	
1500	1049.0	1497.6	
1600	1000.0	1500.0	
1700	951.0	1497.6	
1800	902.4	1490.4	
1900	854.9	1478.5	
2000	808.7	1461.9	
2100	764.3	1441.0	
2200	722.2	1415.7	
2300	682.8	1386.5	
2400	646.4	1353.6	
2500	613.5	1317.2	
2600	584.3	1277.8	
2700	559.0	1235.7	
2800	583.1	1191.3	
2900	521.5	1145.1	
3000	509.6	1097.6	
3100	502.4	1049.0	
3200	500.0	1000.0	
3300	502.4	951.0	
3400	509.6	903.4	
3500	521.5	854.9	
3600	538.1	808.7	
3700	559.0	764.3	
3800	584.3	722.2	
3900	613.5	682.8	
4000	646.4	646.4	
4100	682.4	613.5	
4200	722.2	584.3	
4300	764.3	559.0	
4400	808.7	538.1	
4500	854.9	521.5	
4600	902.4	509.6	
4700	951.0	502.4	
4800	1000.0	500.0	
4900	1049	502.4	
5000	1097.6	509.6	
5100	1145.1	521.5	
5200	1193.3	538.1	
5300	1235.7	559.0	
5400	1277.8	584.3	
5500	1317.2	613.5	

Mils	L	R	Computer Reading
5600	1353.6	646.4	
5700	1386.5	682.8	
5800	1415.7	722.2	
5900	1441.0	764.3	
6000	1461.9	808.7	
6100	1478.5	854.9	
6200	1490.4	903.4	
6300	1497.6	951.0	
6400	1500.0	1000.0	

FIG. 1   TYPICAL FREQUENCY RESPONSE OF
           SHORT-RANGE MISSILE LAUNCH
           LOCATOR AN/TNS-5 SER. 2
           ELECTRICAL SIGNAL INPUT - 0.175 VOLTS RMS
           FILTER SETTING, 0-100 CPS
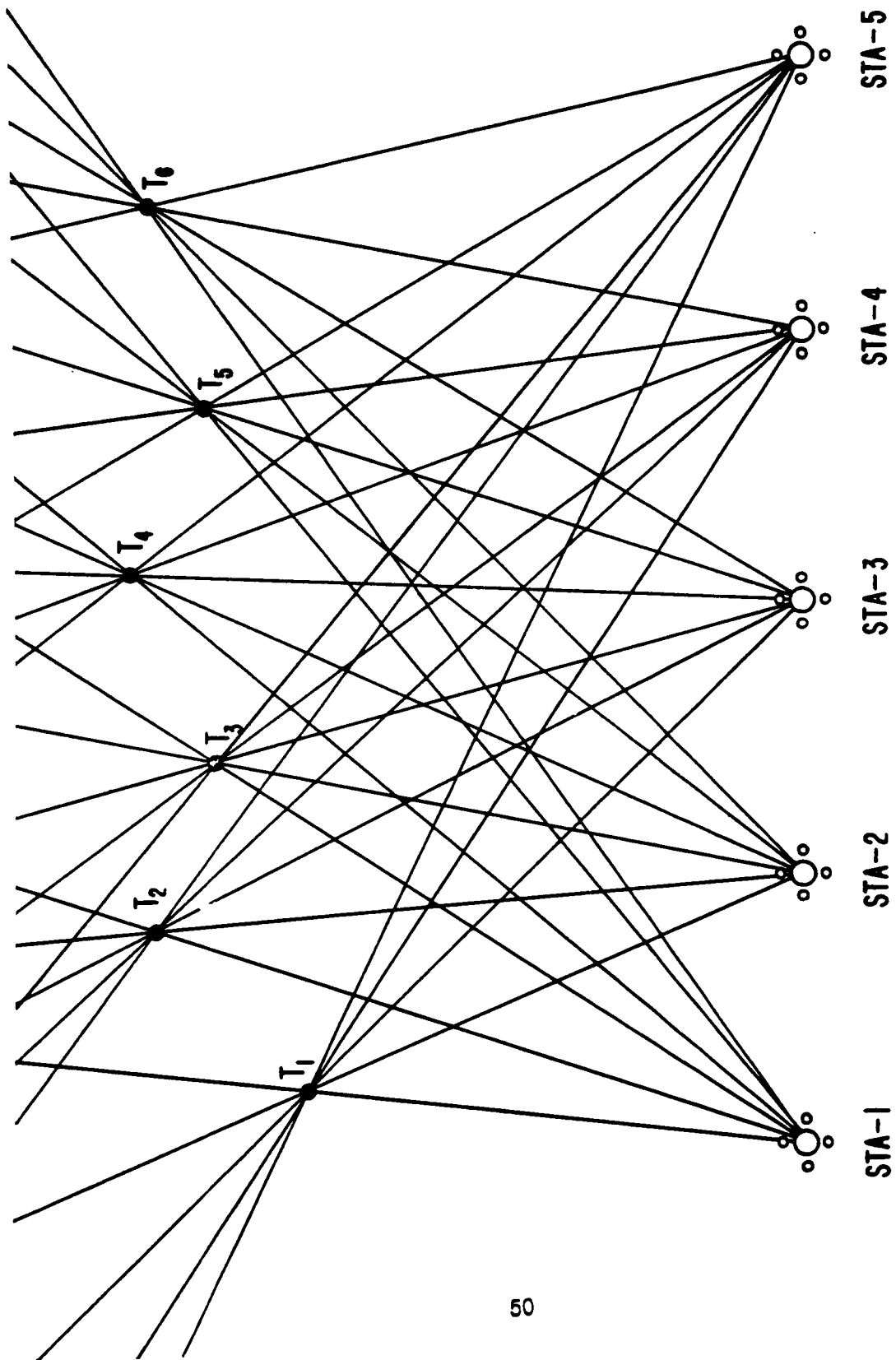   VERTICAL SCALE IN 64THS OF AN INCH

OUTPUT SIGNAL LEVEL AT OSCILLOSCOPE

FREQUENCY CPS

56
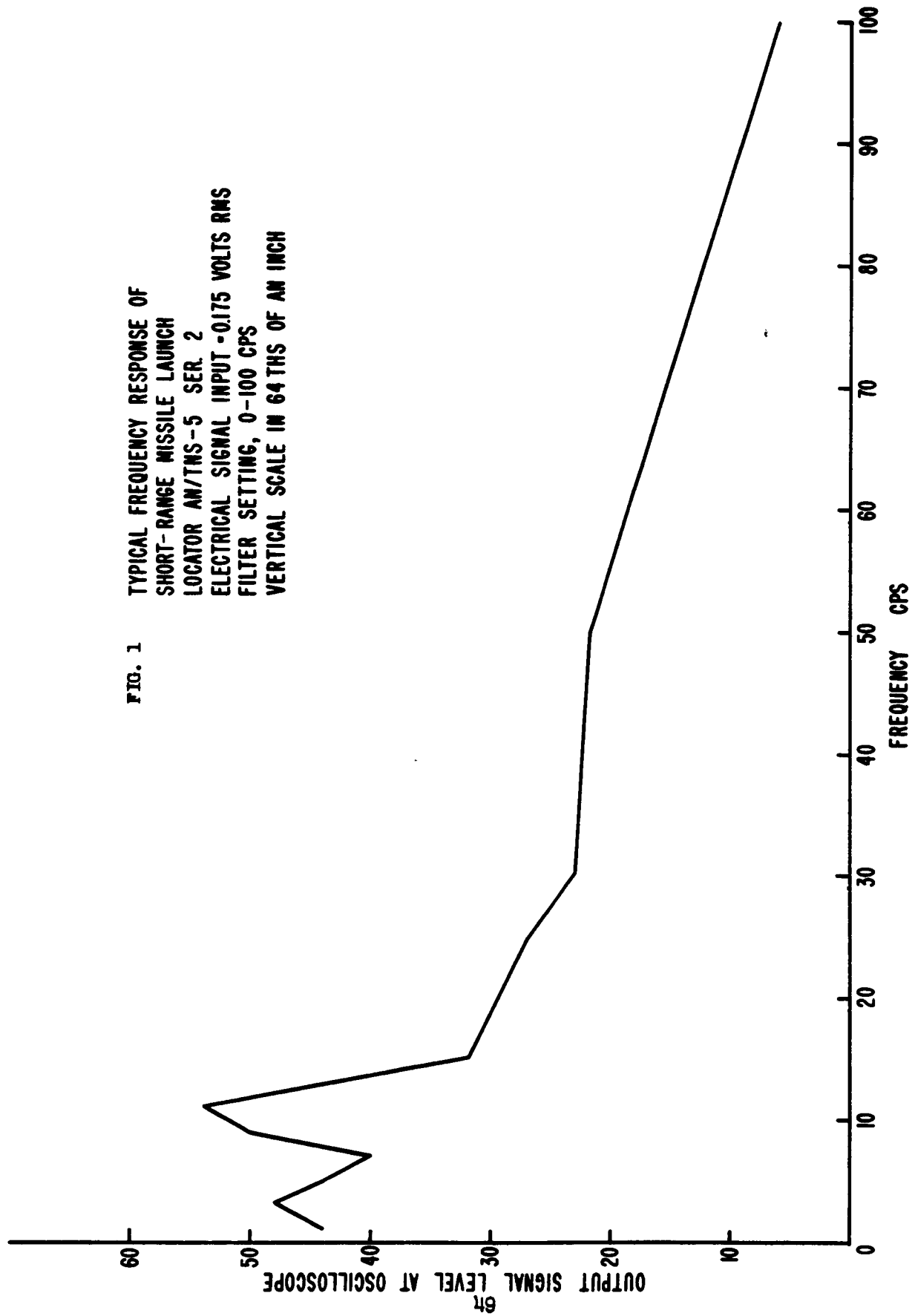
FIG. 2 INTERSECTIONS PRODUCED BY FIVE AN/TNS-5 STATIONS RANGING ON SIX TARGETS.

50

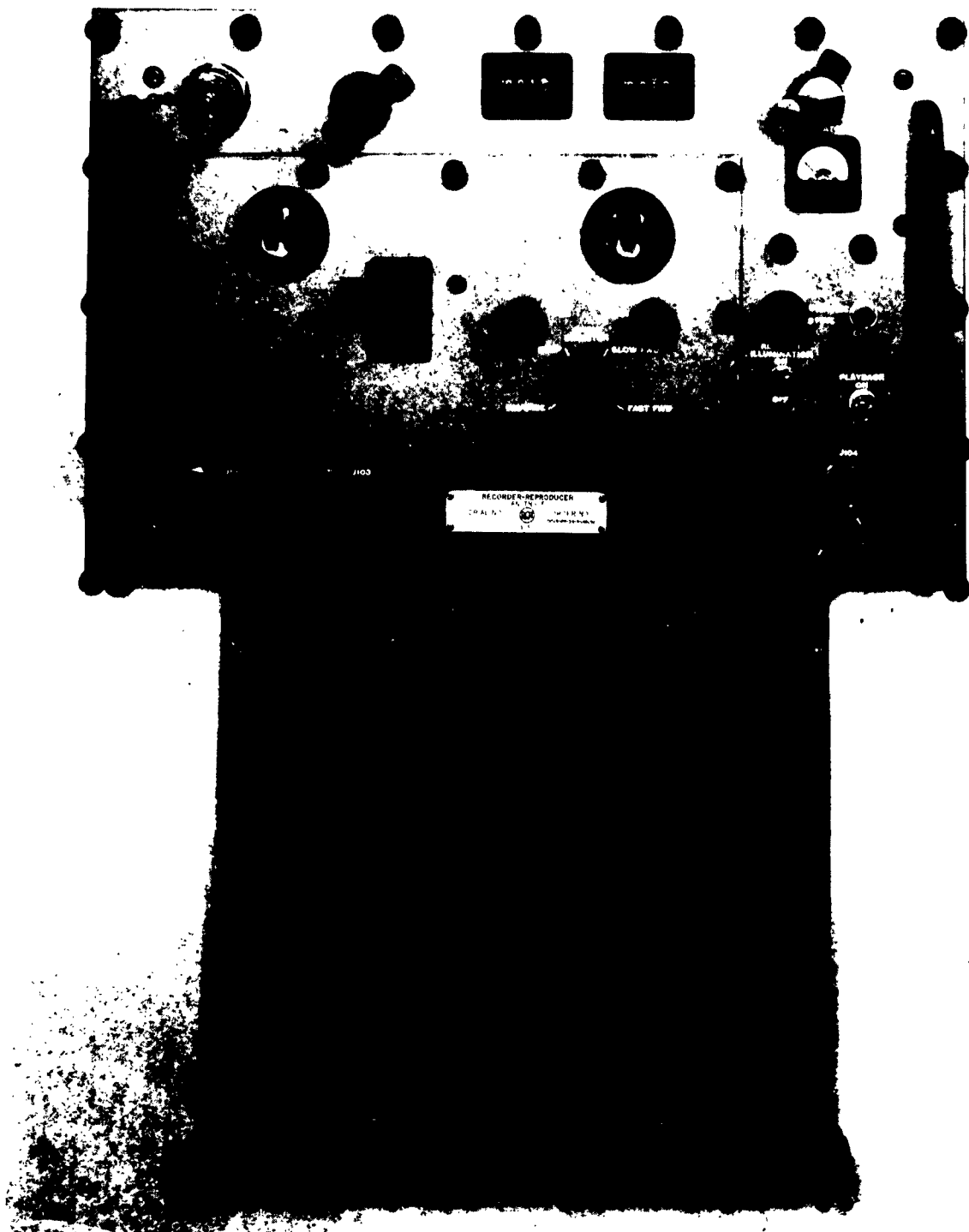FIG. 2 STABLE LOW-FREQUENCY SOURCE FOR AN/TNS-5

SIGRA/SL-62-805

SHORT RANGE MISSILE LOCATOR AN/TNS-5

A SOUND RANGING DEVICE ALLOWING FIELD ARTILLERY PERSONNEL
TO LOCATE ENEMY GUN OR MORTAR POSITIONS

5 JUN 62

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY

FORT MONMOUTH, N. J.

SIGRA/SL-61-757   FORT MONMOUTH, N. J.
            RECORDER-REPRODUCER . (ENGINEERING-TEST)
        PART OF SHORT RANGE MISSILE LOCATOR AN/TNS-5
            MFR. RADIO CORPORATION OF AMERICA
      FRONT VIEW . SHOWING EQUIPMENT REMOVED FROM CASE
          SHOWING TAPE STORAGE BIN BELOW MAIN UNIT
                                              10 MAY 61
      U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY
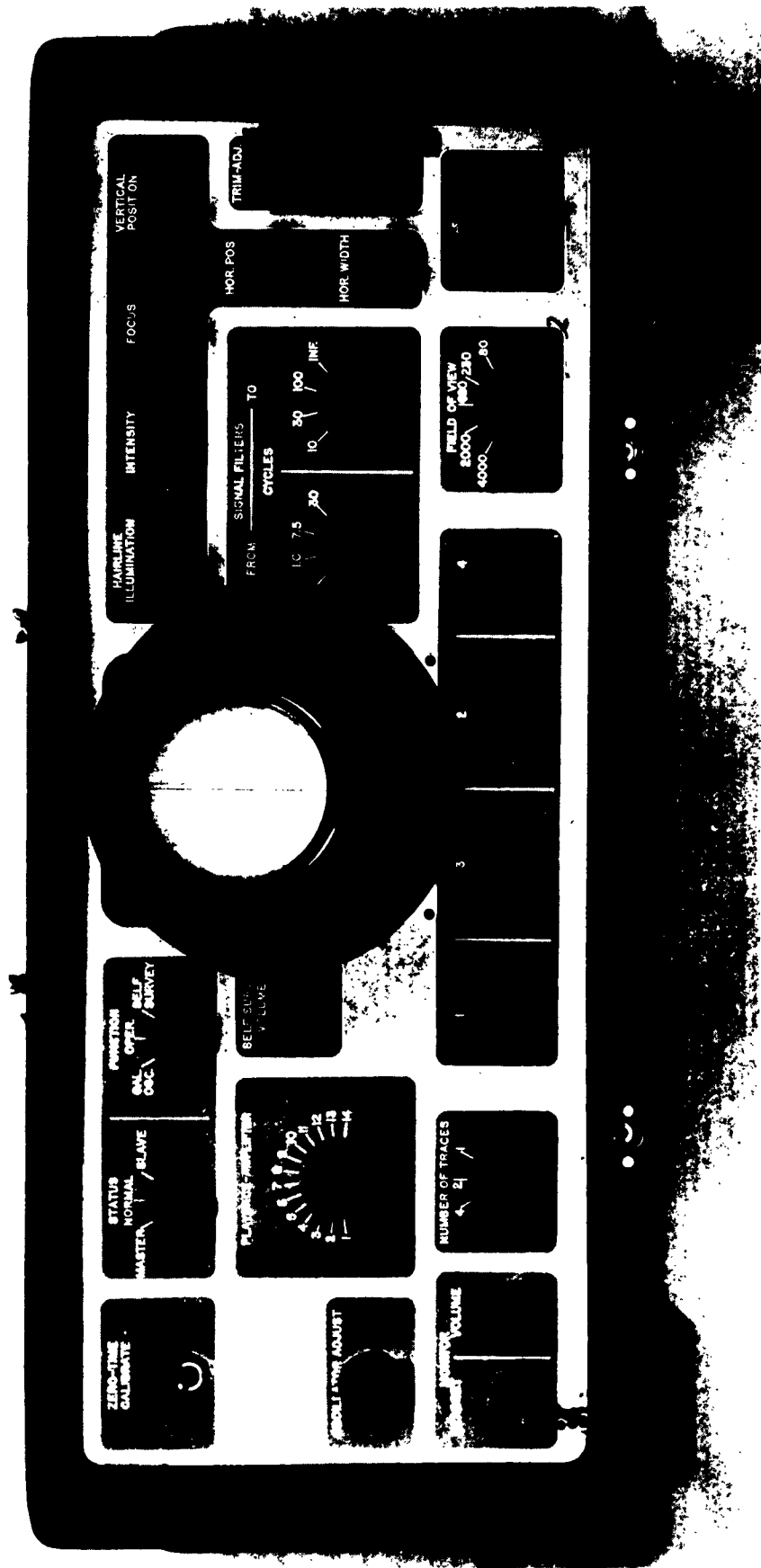
SIGRA/SL-61-760

FORT MONMOUTH, N. J.

SIGNAL ANALYZER . (Engineering-Test)

PART OF SHORT RANGE MISSILE LOCATOR AN/TNS-5

MFR. RADIO CORPORATION OF AMERICA

FRONT VIEW . SHOWING PANEL   10 MAY 61

U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY

AMPLIFIER
BALANCE

ON

COMPUTER
AN/TNS-5
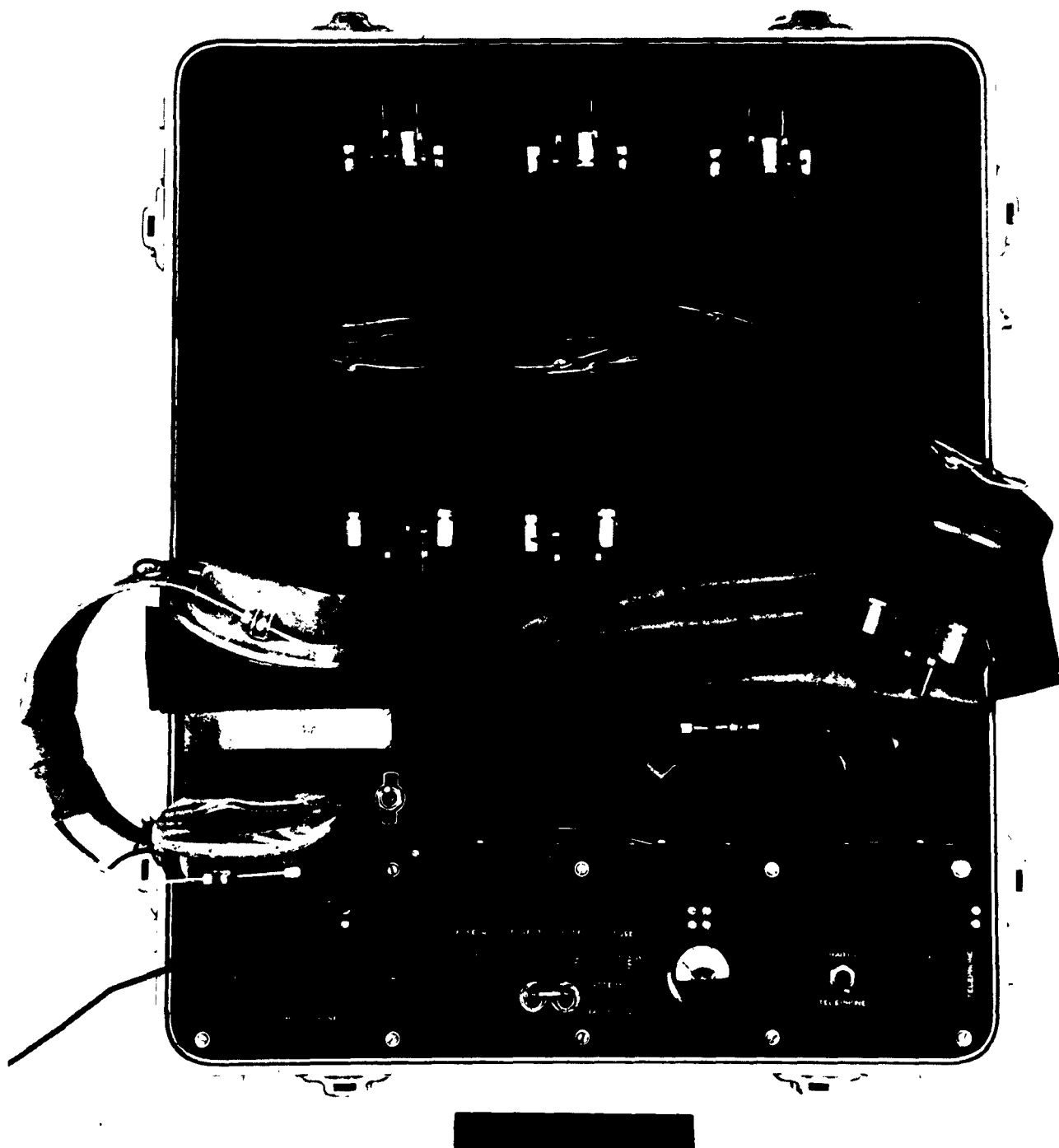SERIAL NO   ORDER NO.
                   0029-PH-59-0142201
X7   U.S.

ARRAY SIZE
METERS

OFF   BRIGHT

.0707
SRC

AMP BAL.
ADJ.

AZIMUTH
MILS

QUADRANT
SRC   AZ

COMPUTE

BEARING
MILS

BEARING

DISTRIBUTION

COPIES

Office of the Assistant Secretary of Defense   1
(Research and Engineering)
ATTN:, Technical Library
Room 3E1065, The Pentagon
Washington 25, D.C.

Commanding General   3
U. S. Army Electronics Command
ATTN: AMSEL-AD
Fort Monmouth, New Jersey

Chief of Research and Development   2
Department of the Army
Washington 25, D.C.

Chief, United States Army Security Agency   1
ATTN: ACofS, G4 (Technical Library)
Arlington Hall Station
Arlington 12, Virginia

Commanding General
U. S. Army Electronics Research & Development Activity   1
ATTN: Technical Library
Fort Huachuca, Arizona

Commanding Officer   1
U. S. Army Electronics Research & Development Activity
ATTN: SELWS-AJ
White Sands, New Mexico

Commanding Officer   1
U. S. Army Electronics Research Unit
P.O. Box 205
Mountain View, California

Commanding Officer   1
U. S. Army Electronics Materiel Support Agency
ATTN: SELMS-ADJ
Fort Monmouth, New Jersey

Headquarters, United States Air Force   2
ATTN: AFCIN
Washington 25, D.C.

Rome Air Development Center　　　　　　　　　　　　　　　　1
ATTN: RAALD
Griffiss Air Force Base, New York

Ground Electronics Engineering Installation Agency　　　1
ATTN: ROZMEL
Griffiss Air Force Base, New York

Aeronautical Systems Division　　　　　　　　　　　　　　1
ATTN: ASAPRL
Wright-Patterson Air Force Base, Ohio

U. S. Air Force Security Service　　　　　　　　　　　　　1
ATTN: ESD
San Antonio, Texas

Strategic Air Command　　　　　　　　　　　　　　　　　　1
ATTN: DOCE
Offutt Air Force Base
Nebraska

Air Proving Ground Center　　　　　　　　　　　　　　　　1
ATTN: PGAPI
Eglin Air Force Base, Florida

Air Force Cambridge Research Laboratories　　　　　　　　2
ATTN: CRXL-R
Laurence G. Hanscom Field
Bedford, Massachusetts

Air Force Systems Command, USAF　　　　　　　　　　　　　1
ATTN: AFSC-STLO-NADC
Johnsville, Pa.

Chief of Naval Research　　　　　　　　　　　　　　　　　1
ATTN: Code 427
Department of the Navy
Washington 25, D.C.

Bureau of Ships Technical Library　　　　　　　　　　　　1
ATTN: Code 312
Main Navy Building, Room 1528
Washington 25, D.C.

Chief, Bureau of Ships　　　　　　　　　　　　　　　　　1
ATTN: Code 454
Department of the Navy
Washington 25, D.C.

COPIES

Hq, Electronic Systems Division   2
ATTN: ESRR & ESSD
Laurence G. Hanscom Field
Bedford, Massachusetts

Chief, Bureau of Ships   1
ATTN: Code 686B
Department of the Navy
Washington 25, D.C.

Director   1
U. S. Naval Research Laboratory
ATTN: Code 2027
Washington 25, D.C.

Commanding Officer & Director   1
U. S. Navy Electronics Laboratory
ATTN: Library
San Diego 52, California

Commander   1
U. S. Naval Ordnance Laboratory
White Oak
Silver Spring 19, Maryland

Director   1
U.S. Army Engineer Research & Development Laboratories
ATTN: Technical Documents Center
Fort Belvoir, Virginia

Commanding Officer   1
U. S. Army Chemical Warfare Laboratories
ATTN: Technical Library, Building 330
Army Chemical Center, Maryland

Commanding General   2
Army Materiel Command
ATTN: R&D Directorate
Washington 25, D. C.

USAERADL Liaison Officer   1
Ordnance Tank Automotive Command
U. S. Army Ordnance Arsenal
Detroit, Center Line, Michigan

COPIES

Commanding Officer   1
Diamond Ordnance Fuse Laboratories
ATTN: Library, Bldg. 92, Room 211
Washington 25, D.C.

USAERADL Liaison Officer   1
Naval Research Laboratory
ATTN: Code 1071
Washington 25, D.C.

USAERADL Liaison Officer   1
Massachusetts Institute of Technology
Building 26, Room 131
77 Massachusetts Avenue
Cambridge 39, Massachusetts

USAERADL Liaison Office   1
Aeronautical Systems Division
ATTN: ASDL-9
Wright-Patterson Air Force Base
Ohio

U. S. Army Research Liaison Office   1·
Lincoln Laboratory
P. O. Box 73
Lexington, Massachusetts

USAERADL Liaison Officer   1
Rome Air Development Center
ATTN: RAOL
Griffiss Air Force Base
New York

Chief, West Coast Office   1
U. S. Army Electronics Research & Development Laboratory
75 South Grand Avenue, Building 13
Pasadena, California

USAEMSA Liaison Engineer   1
Signal Section, Eighth U. S. Army
A.P.O. 301
San Francisco, California

Chief Scientist, SELRA/SL-CS, Hq, USAERADL   1

USAERADA-White Sands Liaison Office, SELRA/SL-LNW, USAERADL   1

Corps of Engineers Liaison Officer, SELRA/SL-LNE, USAERADL   1

Marine Corps Liaison Officer, SELRA/SL-LNR, USAERADL   1

Copies

Hq, Electronic Systems Division   1
ATTN: ESAT
L. G. Hanscom Field
Bedford, Massachusetts

Hq, Research and Technology Division   1
ATTN: RTH
Bolling AF Base
Washington 25, D. C.

USAERADL Liaison Office   1
USA Combat Developments Command
Fort Belvoir, Virginia

U. S. Army Combat Developments Command Liaison Office,   3
    SEIRA/SL-LNF, USAERADL

Air Force Systems Command Scientific/Technical Liaison Office, 1
    SEIRA/SL-LNA, USAERADL

Commanding Officer, U.S. Army Signal Research Activity,   1
    Evans Area

Chief, Technical Information Division, Hq, USAERADL   2

USAERADL Technical Documents Center, Evans Area   1

File Unit Nr. 1, Rm 3C-133, Hexagon   1

Director, Applied Physics Division, Surveillance Dept.,   2
    USAERADL

Director, Surveillance Dept., USAERADL   2

Chief, Reconnaissance Branch, Applied Physics Division,   25
    USAERADL